12-1990

The Reproductive Biology, Winter Dormancy and Denning Physiology of Black Bears in Great Smoky Mountains National Park

Stephen Anthony Pozzanghera
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Stephen Anthony Pozzanghera entitled "The Reproductive Biology, Winter Dormancy and Denning Physiology of Black Bears in Great Smoky Mountains National Park." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

Michael R. Pelton, Major Professor

We have read this thesis and recommend its acceptance:

Boyd L. Dearden, James D. Godkin, Patricia B. Coulson

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Stephen Anthony Pozzanghera entitled "The Reproductive Biology, Winter Dormancy and Denning Physiology of Black Bears in Great Smoky Mountains National Park." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

Michael R. Pelton, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:

Vice Provost
and Dean of the Graduate School

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a Master's degree at The University of Tennessee, Knoxville, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of the source is made.

Permission for extensive quotation from or reproduction of this thesis may be granted by my major professor, or in his absence, by the Head of Interlibrary Services when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Signature Stephen A. Bozzangera

Date 8/16/90

THE REPRODUCTIVE BIOLOGY, WINTER DORMANCY AND DENNING PHYSIOLOGY OF BLACK BEARS IN GREAT SMOKY MOUNTAINS NATIONAL PARK

A thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Stephen Anthony Pozzanghera

December 1990

DEDICATION

To the memory of my grandfather Anthony Lucia. Good fishing partners are never forgotten.

ACKNOWLEDGMENTS

This study would not have been possible without the assistance of numerous individuals. Having taken six years to complete, I undoubtedly have forgotten someone. Please excuse any oversights.

My friend and major professor Mike Pelton provided enthusiasm, support and his expertise whenever needed. He also showed tremendous patience in seeing this project to completion; I am indebted to him. Committee members Boyd Dearden, Jim Godkin and Pat Coulson provided advice and review of the final manuscript. Pat Coulson and members of her staff at the Tennessee Endocrine Reference Laboratory handled all blood sample analyses and assisted with their interpretation. Bruce Hastings provided moral support, advice and a willingness to help in any way possible. Greg Wathen, Doug Scott and Larry Marcum of the Tennessee Wildlife Resources Agency provided mast data. Greg Wathen also provided field advice and early manuscript review. The cooperation and assistance of the National Park Service was invaluable and Stu Coleman, Bill Cook, Kim Delozier, Don Dollar, Rick Yates and "Robbie" Robinson were important to the success of this project. A host of students and research associates added greatly to my graduate school "experience". They include: Dave Kocka, Greg Pierce, Jane Griess, Katie Greenberg, Billy Minser and Ken Johnson. Jeff Beringer, fellow grad student and "trailer-mate", provided his support, field knowledge, assistance and friendship and is responsible for my maintaining some degree of sanity throughout this study...thank you. Summer field assistants included Bill Smith, Mike Murdoch, Morton Heim, Iver Mysterud and Bert Nolan; traplines would have been impossible to operate and maintain without their effort. Cliff Rice provided assistance and was instrumental in developing the proper technique for darting a free-ranging rhododendron. Winter den work was accomplished with the help of Sterling College intern's Laurie Chrysostom-Lockwood and Scott Lang. Pilot Bill Kindy provided hours of flight time to monitor bears and locate dens and was responsible for getting us out of some tricky moments at Devils Courthouse. Ken and Jennifer Voorhis and a multitude of members of the Great Smoky Mountain Institute at Tremont provided a home away from home; their kindness will not be forgotten. Tremont also provided me with an introduction to my wife Betsy and that is the real reason for my love of the mountains. During the writing stage of this project Pete and Carol Ann McLean opened their hearts and their home. Pete McLean also offered criticism and advice and reviewed portions of this manuscript. Fellow employees of The North Carolina Wildlife Resources Commission have provided understanding and patience while urging me to complete this thesis; they include Carl Betsill, Grady Barnes, Terry Sharpe, Wib Owen and Jack Donnelly. Mike Carraway, also with the Commission, and Carol Sawyer with the North Carolina Museum of Life and Science offered their computer graphics expertise in creating figures for this manuscript. My "acquired" parents Bill and Karol Childs helped Betsy deal with my thesis moods and were gracious enough not to ask how "it" was coming every time they called. My brother, Keith Pozzanghera and sister Anita Kowalski provided long distance love, reassurance and laughter. Keith also provided the illustration for Appendix A. My grandmother, Anna Lucia, has always been a model of optimism and perseverance. Lastly, to my parents Sam and Connie Pozzanghera for their unending love and continual support. Without them this project would have remained only a dream, with them it has become a reality.

ABSTRACT

Black bear reproduction, winter dormancy and denning physiology were studied during June 1984 to May 1986 in the northwest quadrant of Great Smoky Mountains National Park, Tennessee. Information was obtained from 30 individual females captured 35 times. Additional information on mast indices, lactation and den utilization were summarized from within the study area for the period from 1978-1988.

Breakaway collar retention varied significantly between years (1984, N=10, $\bar{X}$=394 days vs. 1985, N=5, $\bar{X}$=196 days, $P<0.05$).

Maximum production potential indices calculated for white, red and all oaks for 1984 and 1985 were 8.74, 19.99, 15.52%, and 35.06, 37.73, 36.45%, respectively. Regression analysis showed a significant relationship between white oak mast maximum production potential indices and the number of lactating females observed seasonally between 1979-1988 (winter: $R^2=0.69$, $P<0.003$, summer: $R^2=0.45$, $P<0.03$, annually: $R^2=0.62$, $P<0.007$).

Using vulval examination, 12 females captured in 1984-1985 were determined to be in estrus. Most observations of estrus occurred between 20 June and 12 August. Females subjectively determined to be in estrus had significantly lower levels of estradiol ($\bar{X}$=11.06 pg/ml, $P<0.005$) than females showing no signs of estrus ($\bar{X}$=25.44 pg/ml). Salivary estradiols from females observed in estrus were

also lower than those from anestrus females; though not significantly ($\bar{X}$=10.12 pg/ml vs. $\bar{X}$=13.80 pg/ml, P>0.2).

The minimum reproductive age for female black bears was 5.2 years with an average of 2.2 cubs/litter. Mean age at first litter was affected largely by nutrition. Four reproductive skips were observed in "first litter" females following the mast failure of 1984.

Females entered dens from 5 to 15 December during 1984 and from 27 November to 30 December during 1985. Females delayed den entry during years of abundant mast.

Den utilization data were compiled from 1978 to 1986. Seventy-two den sites for 27 adult females were categorized. Tree dens were used more frequently than ground dens (58.3%, N=42 vs. 41.7%, N=30, respectively). However, a majority of litters (16/29, 55.1%) were produced by females denning on the ground.

Ratios of serum urea to creatinine showed slight seasonal decreases (not significant) in 3 of 4 years examined. Urea to creatinine ratios obtained from 5 denned females were not indicative of bears in a physiological state of dormancy ($\bar{X}$=30.96 pg/ml). This finding coupled with observations on winter lethargy at den sites, suggests that the degree of dormancy attained by black bears may differ both within and between geographic regions.

TABLE OF CONTENTS

PAGE

LIST OF TABLES

TABLE PAGE

LIST OF FIGURES

FIGURE PAGE

CHAPTER I

INTRODUCTION

Understanding the reproductive biology and denning behavior of the black bear (Ursus americanus) is essential to the development of current and future bear management strategies. As bear habitat continues to be degraded, fragmented and lost, cumulative productivity data will be needed to construct biologically sound conservation goals for this species.

The black bear is a classic K-strategist. Females are slow to sexually mature, produce few offspring, and provide an extended period of maternal care to their young. The reproductive cycle is generally 2 years in length with breeding activity occurring in alternate years. Given this restricted reproductive capacity, local populations can be impacted in a short time period if birthing success falters in successive years (eg., under conditions of crop or mast failures). Continuous and effective population monitoring is particularly critical for any K-selected species.

Numerous investigations, conducted in different geographic regions of the bears' range, have examined the reproductive biology and denning ecology of the species. Generally speaking, black bears reach sexual maturity between the ages of 2.5 and 5.5. Most breeding activity takes place during June and July (Erickson and Nellor 1964) though an extended season from May (Wimsatt 1963) to August

(Jonkel and Cowan 1971, Poelker and Hartwell 1973, Eiler et al. 1989) has been reported. Females show a seasonally constant period of estrus and are thought to be induced ovulators (Erickson and Nellor 1964). Male to female bonds are not permanent (the species is polygamous) and males play no part in raising offspring.

Black bears exhibit delayed implantation (Wimsatt 1963). After fertilization of the ovum and development into a blastocyst, growth ceases. The blastocyst is carried within the uterine lumen for 5 months prior to implantation. Implantation occurs in November and/or December (Foresman and Daniel 1983) and parturition occurs (while the female is dormant) approximately 6 to 8 weeks after implantation (Wimsatt 1963). Total gestation is considered to be 7 to 7.5 months.

Cubs are altricial at birth, but grow rapidly. They emerge from the den with their mother in April-May and will den with her the following winter as yearlings. Nursing by cubs during late spring and early summer is thought to prevent the maternal female from entering estrus during that breeding season.

The denning behavior and physiology associated with dormancy in the black bear are fascinating adaptations for survival. Unlike members of the family sciuridae (ie., woodchucks, chipmunks and ground squirrels), black bears are not deep hibernators. The condition differs in that black bears, during their period of inactivity, are independent of food and water, maintain near normal body temperature, can be easily aroused and produce young (Nelson 1973). In the metabolic sense, black bears circumvent the need for food intake during dormancy by relying primarily on body fat stores (Nelson 1973). To prevent the problem of uremia and dehydration during their extended fast, bears, "while catabolic in fat metabolism, reverse metabolism of body proteins from a catabolic to an anabolic state" (Nelson 1983). The result at the end of hibernation is weight loss that is resticted to body fat and not lean body mass (Nelson 1983).

The University of Tennessee has conducted field investigations into the reproductive biology and denning ecology of black bears in the Southern Appalachians since 1978 (Eiler 1981, Wathen 1983). This study is a complimentary work to the initial investigations of Eiler (1981) and Wathen (1983) and reports on basic reproductive parameters such as breeding season, minimum reproductive age and litter size and also summarizes Southern Appalachian data on the relationship between oak mast, bear productivity and den utilization. The phenomenon of winter sleep and the relationship of serum urea and creatinine to the state of dormancy in denning black bears (Nelson 1984) was also examined.

CHAPTER II

STUDY AREA

Location

Research was conducted within the northwest quadrant of Great Smoky Mountain National Park (GSMNP or Park). The area encompasses 506 km^2 in Blount and Sevier counties, Tennessee, and is bordered to the east by US Highway 441, to the south by the Tennessee state line and to the west by the National Park Service (NPS) boundary (Fig. 1). Access to the study area is by 64 km of improved roads, 88 km of unimproved roads, 400 km of maintained foot trails and over 240 km of abandoned trails, railroad beds and logging roads. The use of improved and unimproved roads facilitated traveling between individual watersheds, while foot trails were used to carry out backcountry trapping. Intensive trapping and winter monitoring efforts centered around four areas:

1) Sugarland Mountain
2) Bote Mountain (including Defeat Ridge and Tremont)
3) Parson Branch Road (including Hannah Mountain and Bunker Hill)
4) Turkeypen Ridge

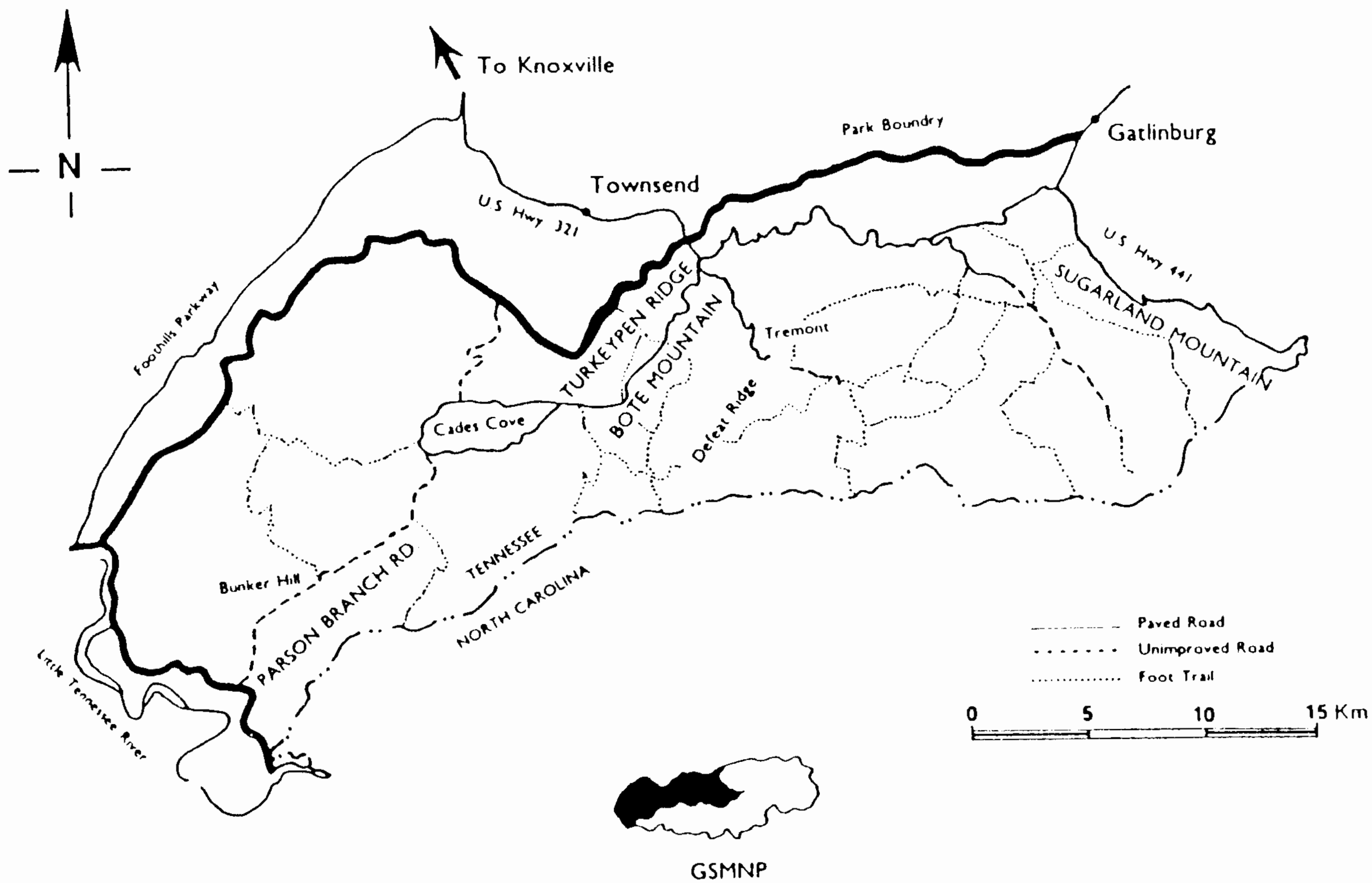

Figure 1. Map of the study area, the northwest quadrant of Great Smoky Mountains National Park.

Physiography and Geology

The Great Smoky Mountains lie in the southern division of the Appalachian Highlands and are part of the Unaka Mountain Range of the Blue Ridge Province (Fennemans 1938). Prominent peaks and finger ridges radiate from the main crest of the range which runs northeast to southwest and forms the southern boundary of the study area. The topography is characterized by sharp ridges and steep, stream-cut valleys. Over 90% of the study area has a slope greater than 10° (Anon. 1902). Elevations range from 265 m at Chilhowee Reservoir to 2,024 m at Clingmans Dome, the second highest peak in the eastern United States (King et al. 1968).

Bedrock and Soil

Bedrock within the study area is that of the Ocoee Series formed during the Precambrian age. Major components of the parent material include quartz, feldspar and slate with small percentages of schist and limestone also present (King et al. 1968). Soils are of the Ramsey association (Anon. 1945) and are characterized by low fertility, low water storage capacity and susceptibility to erosion and leaching. Cain (1930) found deep alluvial soil deposits at the base of slopes and along riparian zones within GSMNP. Shallow soils are characteristically found along the Park's ridges and steep slopes.

Climate

Thornthwaite (1948) classified the climate of the area as that of a warm-temperate rain forest (mesothermal perhumid). Noticeable temperature and precipitation changes accompany elevational rise (Shanks 1954a, Stephens 1969), with a mean annual temperature of 14° C below 450 m and 8° C above 1900 m. Stephens (1969) reported the lowest and highest temperatures occurring in February and July, respectively. Average annual precipitation ranges from 140 cm at lower elevations to 220 cm at higher elevations (Stephens 1969). Periods of peak precipitation occur during late winter and midsummer. Fall is considered the driest season (Dickson 1960). Snow accumulation during the winter is slight, with an annual average of 16 days receiving snowfall.

Vegetation

Geologically created extremes in elevation, precipitation, and temperature combined with the glacial deposition of northern species has created a tremendous diversity in the flora of the Great Smoky Mountains. Stupka (1960) reported over 1,300 flowering plant and tree species within GSMNP. Species accounts for the area also include 230 lichens, 2,000 fungi and over 350 mosses and liverworts (Stupka 1960). Several researchers have categorized different forest types within the Park (Shanks 1954b, Whittaker 1956, Golden 1974). The classification system of Shanks (1954b) is the most widely accepted and was used by Eiler (1981), Wathen (1983) and this study. Personal observation within the four major portions of the study area yielded the following forest type associations: **Sugarland Mountain** showed the greatest forest type diversity with representation of the cove hardwood, northern hardwood and closed oak associations. Hemlock was encountered within a wide elevational range along riparian zones and sheltered northern slopes; this was also the only portion of the study area in which high elevational (> 1500 m) spruce-fir forests were encountered. The **Bote Mountain** ridge was characterized by low and mid elevational closed oak and open oak-pine forest types. Table mountain pine (*Pinus pungens*), although not listed by Shanks (1954b), was the dominant species along the main ridge. Dropping off of Bote Mountain and into the Defeat Ridge and Tremont regions, northern hardwood and hemlock predominated. **Parson Branch Road** was dominated by cove and northern hardwoods. Large stands of hemlock (*Tsuga canadensis*) were noted in the Rabbit and Panther Creek drainages. The Bunker Hill area, located off of Parson Branch Road, was an exposed, xeric ridge characterized almost exclusively by open oak-pine forest.

Dominate understory species encountered throughout the study area, included blueberry (*Vaccinium* spp.), huckleberry (*Gaylussacia* spp.), rhododendron (*Rhododendron maximum*) and mountain-laurel (<u>Kalmia latifolia</u>). The latter two often form impenetrable thickets devoid of an overstory.

Wildlife

The same geologic and glacial forces creating floral diversity within GSMNP have acted upon the local fauna. Linzey and Linzey (1971) listed 59 species of mammals in the Park. Nearly half of that total is comprised of members of the Order Rodentia. Large mammals present within the study area include the black bear, white-tailed deer (<u>Odocoileus virginianus</u>) and european wild boar (<u>Sus Scrofa</u>). River otter (<u>Lutra canadensis</u>) were reintroduced into Abrams Creek during the last season of this study (Griess 1987).

King and Stupka (1950) reported over 200 bird species throughout the southern Appalachians. Passerines were readily observed throughout the study area. Spring and fall hawk migrations were noted during both field seasons and peregrine falcons (<u>Falco peregrines</u>) were reintroduced into the Park during the course of this study and observed on two separate occasions from Sugarland Mountain.

The Park also boasts of 130 species of reptiles, 39 species of amphibians and 72 species of fish. Copperheads (<u>Agkistrodon contortrix</u>), and timber rattlesnakes (<u>Crotalus horridus</u>), were not uncommon sights while afield. The rainbow trout (<u>Salmo gairdneri</u>) provides excellent sportfishing opportunity for Park anglers and fishing pressure within the study areas' backcountry fluctuated seasonally (pers. obs.).

Park History and Use

The mountains of the southern Appalachians gave in grudgingly to determined white settlers. But, by the turn of the twentieth century, 85% of the Great Smokies were owned by timber and pulpwood companies. The remaining lands were dotted by some 6,000 small farms and homesites.

In 1899, Dr. Chase Ambler began the push for a national park by organizing the Appalachian National Park Association (Frome 1985). Unlike public domain lands of the western United States, land acquisition in the populated east proved to be a long and arduous task. In 1924, a committee appointed by the Secretary of the Interior surveyed the Appalachians and was to recommend the best location for a park (Frome 1985). The Great Smoky Mountains were chosen. Congressional legislation was passed in 1926, essentially granting permission to proceed with the creation of a national park. A gift of 5 million dollars by John D. Rockefeller, Jr., in 1928, paved the way for land purchasing (Frome 1985). However, it was not until 1934 that the land acquisition of 517,014 acres was complete and Great Smoky Mountains National Park was born (Lambert 1961). Final dedication of the park took place in 1940 when president

Franklin D. Roosevelt entertained a group of 2,000 visitors at Clingmans Dome.

Today, Great Smoky Mountains National Park is the most visited park in the country, averaging over 9 million visits a year. During 1984, the first year of this study, the Park celebrated its Golden Anniversary. Public response to NPS promotional campaigns was excellent and 8,508,400 visits were made to the Smokies. The surprise came during the second year of this study, 1985, when an all-time record of 9,319,300 visits were tallied. During 1984 and 1985, 58% of all visits to the Park were recorded through the Gatlinburg and Townsend entrances within the study area.

The variety of recreational opportunity within GSMNP seems to be limited only by a visitor's imagination. However, certain activities became important considerations in this study due to the utilization of the backcountry as both a recreational and a research resource. The average number of visits made Parkwide, during the two years of this study, by day hikers was 248,612. Horseback riders and backcountry campers accounted for 66,731 and 64,929 visits, respectively. Fisherman made 19,650 visits to the streams within the Park. Lastly, auto-tourists traveled on Parson Branch Road a total of 7,008 times.

CHAPTER III

MATERIALS AND METHODS

Capture, Immobilization and Handling Techniques

Black bears were captured with Aldrich (Clallam Bay, WA) and Fremont (Candle Lake, Saskatchewan) foot snares using the prebaiting and trapping procedures described by Johnson and Pelton (1980). Trapping was conducted from the first week of June to the middle of September. Single portions of the study area were trapped systematically for 14 days at a time. Traps were then closed and relocated. All traps were checked daily beginning at 0630 h. Snares located on Parson Branch Road were checked by vehicle. All other traplines were checked on foot. During 1984 a backcountry camp was established to trap the Defeat Ridge portion of Bote Mountain; this line was abandoned in 1985. Traditional log cubby sets were modified using burlap sheets 102 cm wide and 4 m long (Appendix A).

Trapped animals were immobilized with a 100:200:20 mg mixture of freeze-dried Rompun (Xylazine, Haver Lockhart, Inc., Shawnee, KS), Ketaset (Ketamine hydrochloride, Bristol Laboratories, Syracuse, NY) and Carbocaine-V (Mepivicaine hydrochloride, Winthrop Laboratories, New York, NY) respectively. The rompun, ketamine and carbocaine (RKC) was administered intramuscularly at a dosage of 2.0 ml/45 kg of estimated body weight and delivered via CAPCHUR dart and CO_2

pistol (Palmer Chemical and Supply Co. Inc., Douglasville, GA).

Once chemically immobilized, all bears were marked with a combination of colored and plain ear tags. The colored tags were either blue or orange. Bears captured on Bote Mountain, Turkeypen Ridge and Sugarland Mountain received blue tags. Orange tags were used in the Parson Branch Road portion of the study area. The plain metallic tags were placed in the opposite unmarked ear for sex differentiation and standardization of placement (ie., all male bears had metallic tags placed in the right ear and colored tags in the left). Upper lip tattoos corresponding to ear tag number were applied to all initial captures and repaired or replaced (as needed) on recaptured individuals. Weight, standard measurements, general condition and other biological data were collected and recorded. A single premolar tooth was taken from all bears for age determination. Teeth were sectioned and stained following the procedures of Eagle and Pelton (1978). Ages were determined using the cementum annuli technique described by Willey (1974). Matson (1981) reported greater aging accuracy within the lower age classes, therefore ages assigned at the time of initial capture were updated to the present study when recording ages of recaptured bears. Female bears $\geq$ 30 kg were fitted with breakaway radio collars (Telonics, Inc., Mesa, AZ) functioning in the 150-

152 MHz range. Breakaway portions of collars were reinforced with several wraps of electrical tape. Sedated bears were observed at a trap site until they had regained consciousness and were able to leave the area under their own power.

Collection of Summer Reproductive Data

Trapped, immobilized, female bears were examined and categorized with respect to lactation and the condition of estrus. Using teat examination, estimates on minimum reproductive age were made for females trapped and observed during the summer and reobserved in their winter den. Teat measurements, swelling of the teats and the condition of guard hairs surrounding the mammaries were used to identify a female that: 1) had nursed a litter in previous years, 2) was currently nursing a litter, or 3) had never nursed a litter. A 1.0 ml intramuscular injection of oxytocin (Burns Veterinary Supply, Oakland , CA) was used to facilitate milk let-down and detect lactation (Eiler 1981:12-13).

Rogers (1977), Eiler (1981) and Wathen (1983) all reported swelling of the external genitalia to be indicative of a female in estrus. Vulval swelling was used to categorize a female as either estrus or anestrus. Wathen (1983), reported that females with swollen genitalia had significantly higher levels of serum estradiol-17B than those showing no external signs of estrus. Blood samples were taken from females for analysis of both total estrogen and estradiol-17B concentrations to compare and expand on the original work of Wathen (1983). Blood samples were obtained from the femoral vein and collected in Vacutainer chemistry tubes containing no additives (Vacutainer Systems, Rutherford, NJ). Blood was returned from the field within 8 hours from the time of collection. Samples were cooled, allowed to clot and centrifuged for 20 minutes. Serum was drawn-off and frozen at The University of Tennessee field laboratory (GSMNP Townsend, TN). At the end of each trapping season, samples were brought to the Tennessee Endocrine Reference Laboratory (TERL, Blount Memorial Hospital, Maryville, TN) for analysis. Total estrogen concentrations were obtained using a direct radioimmunoassay and reagents from Radioassay Systems Lab (Carson, CA). Serum estradiol-17B concentrations were extracted from total estrogens in the manner described by Wathen (1983:16). To investigate the physiological state of winter dormancy or lethargy in the black bear, remaining sample fractions were deproteinized (due to the lipemic nature of bear sera) and analyzed for urea nitrogen and creatinine . Serum samples collected within GSMNP in 1980-81 (Wathen 1983:16) were also analyzed and provided both a means for increasing sample size and annual comparison. Bear activity, behavior and temperament were noted during winter den visits in 1985-86. Urea nitrogen concentration was determined using Sigma

Diagnostics Procedure number 535, essentially, the diacetyl monoxime method as modified by Crocker (1967). Urea was calculated as the urea nitrogen concentration divided by 0.466 (Nelson, et al. 1984). Serum creatinine was determined using the Heinegard and Tiderstrom method (1973) and Sigma Diagnostics Procedure number 555.

Walker (1983) felt that analysis of steroids in human saliva provided valuable information in the area of endocrine research. Theoretically, techniques used to assay human salivary steroids should work on a large mammal such as the black bear. Estradiol-17B concentrations within saliva could be used against those in blood serum to further investigate the relationship between vulval swelling and elevated estradiol levels. During the 1985 trapping season, saliva samples were successfully collected from immobilized female bears using subcutaneous injections of 5 mg Urecholine (Bethanol Chloride, Merck Sharp and Dohme, West Point, PA) (Pozzanghera et al. 1986). Saliva was aspirated from the mouth using a 5 cc syringe and stored in Vacutainer tubes (Vacutainer Systems, Rutherford, NJ). Saliva samples were returned from the field within 8 hours of collection. Samples were centrifuged for 10 minutes to separate out solid contaminants and then frozen. Assay techniques for salivary total estrogens and estradiol-17B concentrations were identical to those used for blood serum.

Collection of Den Entry Data

Ground triangulation and aerial radio tracking of bears was begun the third week of November. Telonics TR-2 receivers and "H" antennas (Telonics Inc., Mesa, AZ) were used to locate animals. Ground tracking techniques used are described by Mech (1983). Aerial tracking was accomplished using the method of Smith (1985:28). Flights were made in a Cessna 172 aircraft every 3 to 5 days (weather permitting). "Den entry" had occurred when an animal was observed to be in the same location for three consecutive tracking sessions. Dates for females entering dens were calculated as the mean between the date of the last location away from the den site and the date of the first location at the den. Telemetric ground tracking to locate dens and den investigation was begun approximately 1 month after den entry.

Collection of Winter Reproductive Data

Dens of radio instrumented females were visited to categorize winter reproductive condition. Females were observed as having: 1) no offspring, 2) newborn cubs or 3) yearlings. Den type, either ground or tree, dictated the data collecting procedure.

Ground denning females were immobilized with RKC delivered via 10 cc syringe and jabstick or CAPCHUR dart and CO_2 pistol (Palmer Chemical and Supply CO., Inc., Douglasville, GA). Winter dosages of RKC were the same as those administered during the trapping season. Adults were examined for general condition, weights were estimated, ear tags and lip tattoos were replaced when necessary. Blood samples were taken using summer methodology. Samples were handled similarly and analyzed for urea nitrogen and creatinine. Radio collars were replaced or removed as needed (See Collar Retention in RESULTS AND DISCUSSION).

Litter size and sex ratios were determined for females with newborn cubs. Cubs were weighed, sexed, measured and examined for varying developmental stage. Following a 1.0 cc injection of oxytocin (Burns Veterinary Supply, Oakland, CA) to stimulate lactation, adults were repositioned in the den. Cubs were returned to their mother and placed near a teat until they had resumed suckling.

Females denning in tree cavities could not be immobilized safely and practically (pers. obs.). Trees were climbed using mountaineering rope and clog ascenders (Eiler 1981:107) and reproductive status noted from the den entrance. Tree den inspection was aided by the use of a battery powered headlamp and pocket mirror. Yearlings present in dens were counted directly, however, sexes could not be determined. Newborn cub vocalizations were recorded using the procedures of Eiler (1981:14) and Wathen (1983:18). Although vocalizations are readily heard from outside a cavity entrance (Pelton pers. comm., pers. obs., this study) recordings were used to verify the presence of cubs. Litter size for cubs of the year was determined by walking into the den area immediately after family emergence and counting cubs directly (Smith 1985:33).

To monitor future den tree reuse in GSMNP, trees containing denned females were marked with aluminum tags placed 1 m from the ground. Tags were enscribed with University identification, and numbers referencing the year of use and the ear tags of the bear. Tree measurements included DBH (cm), height of the cavity entrance (m), maximum cavity opening dimensions (cm) and depth of cavity (estimated in meters). Tree species, forest type, understory, slope aspect and aspect of den entrance were also noted.

Orphaned Cub Reintroductions

Four orphaned bear cubs were acquired by the National Park Service during late summer and fall of 1984. The two male and two female cubs were orphaned following separate auto collisions resulting in the mothers' deaths. One male cub was taken to The University of Tennessee Veterinary Clinic, Knoxville, where surgery was required to set and pin a fractured tibia. This cub also was believed to be partially blind in one eye. Following post-operative recuperation, this cub was placed with the others. The three remaining cubs were, and remained, in good physical condition.

Following several months of captivity marked by substantial weight gain, the four cubs were examined, weighed, tagged, tattooed and radio-instrumented with breakaway collars. The 10 month old bears were then released into the Elkmont section of the study area. An attempt was made to maintain radio contact with these animals and investigate their post release behavior. The fate of these 4 individuals is reported on in Appendix B.

Oak Mast: Sampling and Calculation of Indices

Fall acorn production (by red oak and white oak group) has been investigated by numerous researchers utilizing different mast survey techniques (Downs and McQuilken 1944, Gysel 1957, Sharp 1958, Sharp and Sprague 1967, Whitehead 1969, Strickland 1972). Seed traps, ground counts and tree counts have all been used to sample fall acorn availability. However, with specific problems inherent to each technique, no "standard" survey procedure exists (Nicholas and White 1984). Both GSMNP and the Tennessee Wildlife Resources Agency (TWRA) currently use the Whitehead tree count survey method (Whitehead 1969), whereby;

- trees are randomly sampled every 0.8 km along established routes

- one vigorous tree (30.5 cm $\leq$ DBH $\leq$ 80 cm) is chosen at each of 8 stops and the percentage of the crown bearing acorns is estimated
- five 90 cm limbs are chosen at random and the number of twigs, number of twigs with acorns and the total number of acorns are recorded for each limb
- limb observations are summed resulting in category totals for each tree.

A TWRA Hard Mast Survey data sheet is included, showing observations recorded for one sample tree (Fig. 2).

Ideally, to investigate any relationships between yearly mast supply (ie., nutrition) and black bear reproductive performance, information on oak production should have been obtained from within the study area itself. Unfortunately, mast data collected by GSMNP employees were both inconsistent and incomplete. Sampling routes were changed, the timing of the surveys was not standardized and low motivation among personnel resulted in poor data collection. Therefore, mast indices were calculated using data gathered annually by TWRA. The mountain counties of Cocke, Sevier, Blount, Unicoi, Greene and Monroe (including The Tellico Wildlife Management Area) which surround the northern boundary of the study area were chosen as the most representative of the Park and used in calculating all mast indices (Fig. 3).

HARD MAST SURVEY

Date________ Area________ County________________ Route #__________ Elevation__________

Species	Limb No.	No. Twigs	No. Twigs w/Acorns	Total No. Acorns
	1			
Code	2			
	3			
% of Crown w/Acorns	4			
	5			
Total	5			

Species	Limb No.	No. Twigs	No. Twigs w/Acorns	Total No. Acorns
	1			
Code	2			
	3			
% of Crown w/Acorns	4			
	5			
Total	5			

Species	Limb No.	No. Twigs	No. Twigs w/Acorns	Total No. Acorns
	1			
Code	2			
	3			
% of Crown w/Acorns	4			
	5			
Total	5			

Species	Limb No.	No. Twigs	No. Twigs w/Acorns	Total No. Acorns
	1			
Code	2			
	3			
% of Crown w/Acorns	4			
	5			
Total	5			

Species	Limb No.	No. Twigs	No. Twigs w/Acorns	Total No. Acorns
	1			
Code	2			
	3			
% of Crown w/Acorns	4			
	5			
Total	5			

Species	Limb No.	No. Twigs	No. Twigs w/Acorns	Total No. Acorns
	1			
Code	2			
	3			
% of Crown w/Acorns	4			
	5			
Total	5			

Species	Limb No.	No. Twigs	No. Twigs w/Acorns	Total No. Acorns
	1			
Code	2			
	3			
% of Crown w/Acorns	4			
	5			
Total	5			

Species	Limb No.	No. Twigs	No. Twigs w/Acorns	Total No. Acorns
	1			
Code	2			
	3			
% of Crown w/Acorns	4			
Total	5			

COMMENTS: ____

____

Name: ____

Figure 2. Tennessee Wildlife Resources Agency hard mast survey data form.

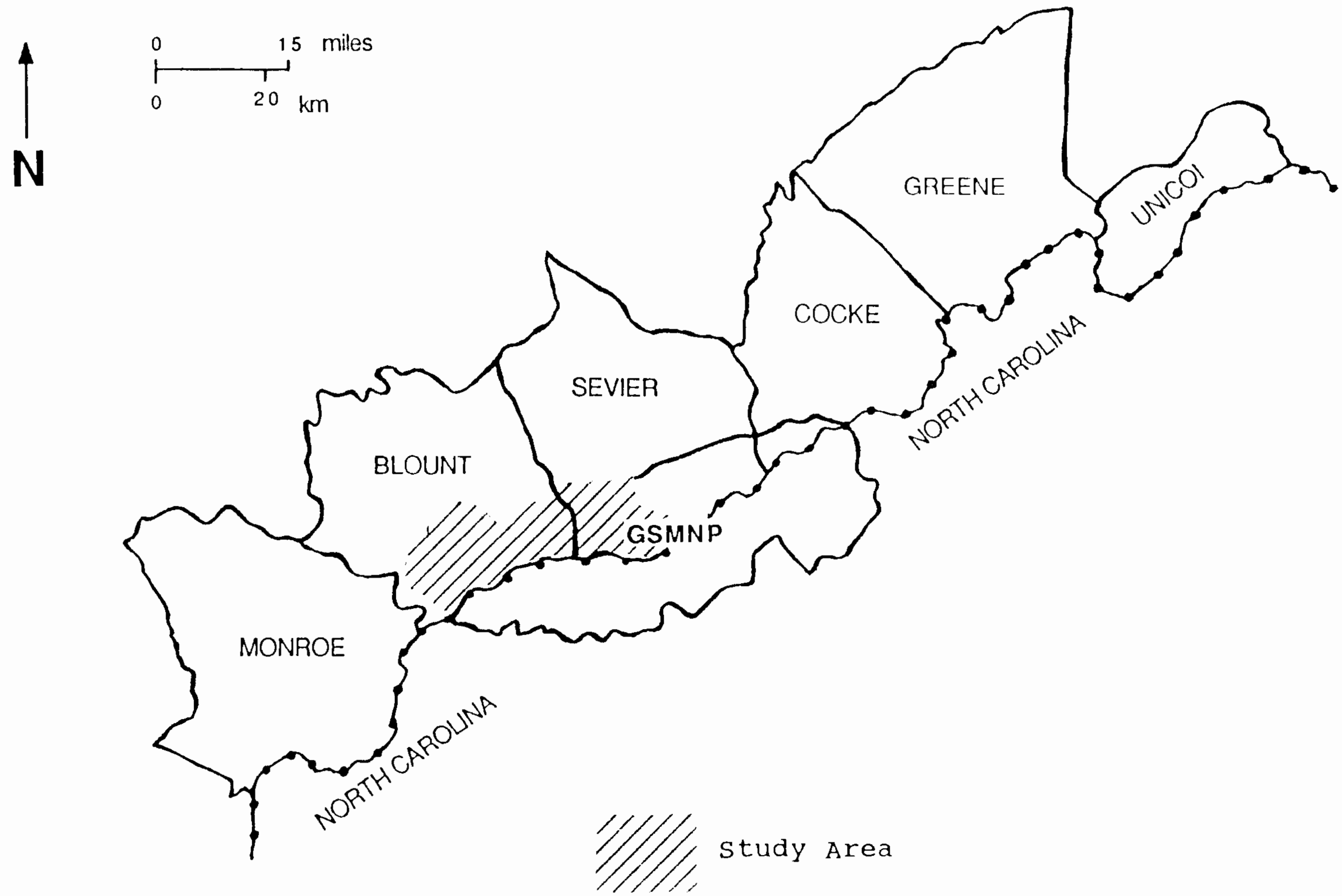

Figure 3. Location of Blount, Cocke, Greene, Sevier, Unicoi and Monroe counties, Tennessee, with respect to the study area.

The intent of a mast survey should be to quantify the data collected and derive some overall index for the mast produced that season. Unfortunately, there are just as many ways of calculating a mast index as there are sampling schemes, with no definitive mathematical bridge connecting field observation of acorns and the numerical index of abundance. Uhlig and Wilson (1952) obtained quantified data by converting their subjective mast classifications of abundant, common, or scarce to a numerical index of 0, 50 and 100. Sharp (1958) derived a quantitative index ranging from 0 to 5 based on the percentage of maximum at which an oak produced acorns. Whitehead (1969) utilized the percentage of twigs bearing acorns and the average number of acorns per twig to calculate an index ranging from 0 to 10. Since both TWRA and the Park employ the Whitehead sampling scheme, it would seem natural to use the Whitehead index for correlation and regression purposes. However, Nicholas and White (1984) state that Whitehead's calculation of the percentage of the crown's twigs bearing acorns has no "biological rationale". That is to say that the percentage of the crown in fruit should be calculated by multiplying total twig number with the number of productive twigs. Instead, Whitehead (1969) adds these two variables together. It also appears that a rating of 10 in the Whitehead index, indicating an "Excellent" mast year, occurs only theoretically and realistically is never achieved (Nicholas pers. comm.). Lastly, Whitehead used the number of acorns per twig in calculating individual tree indices without considering a fruiting maximum. Sharp (1958) calculated such a maximum for both red oak and white oak groups during a bumper year and arrived at a maximum production index. Thus, mast indices by year and oak group (ie., white, red and all oaks combined), were recalculated using the recommendations of Nicholas and White (1984). Essentially, a biologically correct Whitehead equation was combined with Sharps' variables for maximum fruiting potentials. The resulting index, hereby referred to as the Maximum Production Potential Index, the MPP Index or MPPI, ranges from 0 to 100 and calculates the percentage at which southern Appalachian oaks are producing acorns in relationship to their theoretical maximum yield.

The following equation was taken from Nicholas and White (1984):

$$Ni = \frac{(Ci * Ti * Fi)}{10^4}$$

where Ni = the percentage of maximum possible mast crop for each sample tree

Ci = the percentage of the crown in fruit for each sample tree

Ti = the percentage of twigs within the productive crown which bear fruit for each sample tree

Fi = the percentage of the maximum number of fruits per twig for each sample tree.

In this equation, dividing by 10^4 scales individual tree indices to between 0 and 100. Unfortunately, in scaling Ni, you must assume that its components (ie., Ci, Ti and Fi) all reach the 100% level during "good" to "excellent" mast years; this simply is not true. It is unrealistic to believe that in above average mast years all oak trees are producing at 100% fruiting capacity, or that all tree crowns are at 100% production and that 100% of the trees' twigs bear acorns (pers. obs., this study). Using Sharp (1958) and Sharp and Sprague (1967) as the only known references for maximum possible fruiting number in oaks, independent scalars were calculated for both the white and red oak groups (as suggested by Nicholas and White 1984) and used in the Nicholas and White equation.

The following rating system of Sharp and Sprague (1967) was used in developing equation scalars for members of the white oak group:

Mast Year (Subjective Rating)	Number of Acorns on Terminal 60 cm of Limb
"Bumper"	19 to 24
"Good"	13 to 18
"Fair"	7 to 12

"Poor"	3 to 6
"Trace" (None)	0 to 2

Using the 5 limb sampling scheme of TWRA and the number of acorns as reported by Sharp and Sprague (1967), the total number of acorns during a "Good" mast year should be $\geq$ 65 (ie., 5 limbs with a minimum of 13 acorns/limb). Similarly, a theoretical 100% yield would be represented by 120 acorns (ie., 5 limbs with a maximum of 24 acorns/limb). Using 1974, 1977, 1981 and 1985 as representative "Good" white oak mast years for the southern Appalachians (Eiler 1981, Wathen 1983, pers. obs., this study), an average maximum for the total number of acorns per 5 limbs was calculated. Only trees producing $\geq$ 65 acorns per 5 limbs (N = 56) were used in calculating the mean. The average number of acorns produced by fruitful white oaks was determined to be 93.8 per 5 limbs. Thus, Fi (the percentage of the maximum number of fruits per twig) was scaled such that:

$$Fi = (TA/93.8) * 100$$

where TA = the total number of acorns recorded on five limbs.

A 100% yield was recorded for any tree producing $\geq$ 93.8 acorns on 5 limbs.

Scalars were developed for both Ci (the percentage of the crown in fruit) and Ti (the percentage of crown twigs bearing fruit) using the same 56 sample trees and representative "Good" mast years. Calculated means for Ci and Ti were 85.8 and 78%, respectively. Therefore, Ci was scaled in the following manner:

$$Ci = (PCPY/85.8) * 100$$

where PCPY = the estimated percentage of the crown in fruit. A 100% maximum for crown fruit production was achieved for any tree with a PCPY value $\geq$ 85.8%. Ti was calculated using:

$$Ti = [(NTWA/NTW)/0.78] * 100$$

where NTWA = the five limb total for the number of twigs with acorns

and NTW = the five limb total for the number of twigs.

Ti reached the scaled 100% maximum level when a tree had $\geq$ 78% of its twigs in fruit.

Returning to the original equation of Nicholas and White (1984), only now using the scaled versions of Ci, Ti and Fi, the percentage of maximum production was calculated for each tree sampled. An overall MPPI (Maximum Production Potential Index) was calculated by summing the individual percentage indices for each tree and dividing by the total number of trees sampled (Table 1).

Sharp (1958) states that the purpose for any mast survey should be "to evaluate the potential producers and not to determine yields of individual trees which inherently are unfruitful". For this reason, trees producing zero acorns were deleted when calculating all MPPI values (both red and white oak indices).

Table 1. SAS (SAS Institute Inc., 1983) program used to calculate white oak mast indices (MPPI) for Blount, Cocke, Greene, Sevier, Unicoi and Monroe Counties, Tennessee, 1978-1988.

```
Options Linesize=80;
Title 'Mast Survey Data for White Oak Group, TWRA 1978-1988'
Data A;
Input YEAR AREA CTY PCPY NTW NTWA TA;
If TA=0 Then Delete;
If TA>=93.8 Then TA=93.8;
If NTW=0 Then NTW=1;
If PCPY>=85.8 Then PCPY=85.8;
Ci=(PCPY/85.8)*100;
Ti=[ (NTWA/NTW)/0.78 ]*100;
If Ti>=78 Then Ti=100;
Fi=(TA/93.8)*100;
Ni=Ci*Ti*Fi/10000;
Cards;

Proc Sort;
By YEAR;

Proc Means Noprint;
By YEAR;
Var Ni;
Output Out=New Ni=Total N=N;

Data B;
Merge A New;
By YEAR;
MPPI=Total/N;

Proc Sort;
By YEAR;

Data C Set;
Merge A New B;
By YEAR;
If First.YEAR;

Proc Print;
Var YEAR N Total MPPI;
```

The following rating system was developed from Sharp and Sprague (1967) and used to calculate equation scalars for members of the red oak group in the same fashion as previously described for the white oaks.

Mast Year (Subjective Rating)	Number of Acorns on Terminal 60 cm of Limb
"Bumper"	25 to 32
"Good"	17 to 24
"Fair"	9 to 16
"Poor"	4 to 8
"Trace" (None)	0 to 3

The years 1974, 1976 and 1985 were chosen as representative "Good" red oak mast years within the mountains of east Tennessee (TWRA unpublished data, pers. obs., this study). The average maximum for the total number of acorns on 5 limbs was calculated using red oaks producing $\geq$ 85 acorns (ie., 5 limbs with a minimum of 17 acorns/limb) ($N = 38$). The average number of acorns produced by fruitful red oaks was calculated to be 120.5 per 5 limbs. Thus, Fi (the percentage of the maximum number of fruits per twig) was scaled in the following manner:

$$Fi = (TA/120.5) * 100$$

where TA = the total number of acorns recorded on five limbs.

The 100% maximum yield was obtained for any tree producing $\geq$ 120.5 acorns on 5 limbs.

Scalars were developed for Ci (the percentage of the crown in fruit) and Ti (the percentage of the twigs bearing fruit) using the same representative years and sample trees (1974, 1976 and 1985, N = 38). Calculated means for Ci and Ti were 91.5 and 78%, respectively. Therefore, Ci was scaled using the following equation:

$$Ci = (PCPY/91.5) * 100$$

where PCPY = the estimated percent of the crown in fruit. Total crown fruit production (100%) was obtained for any tree with a PCPY value $\geq$ 91.5%. Ti was calculated as:

$$Ti = [(NTWA/NTW)/0.78] * 100$$

where NTWA = the five limb total for the number of twigs with acorns

and NTW = the five limb total for the number of twigs.

Ti was scaled to the 100% maximum level when a tree had $\geq$ 78% of its twigs in fruit.

Finally, overall MPPI'^{s} were calculated for the red oak group by summing the individual percentage indices for each tree and dividing by the total number of trees sampled (Table 2).

Table 2. SAS (SAS Institute Inc., 1983) program used to calculate red oak mast indices (MPPI) for Blount, Cocke, Greene, Sevier, Unicoi and Monroe Counties, Tennessee, 1978-1988.

```
Options Linesize=80;
Title 'Mast Survey Data for Red Oak Group, TWRA, 1978-1988';
Data A;
Input YEAR AREA CTY PCPY NTW NTWA TA;
If TA=0 Then Delete;
If TA>=120.5 Then TA=120.5;
If NTW=0 Then NTW=1;
If PCPY>=91.5 Then PCPY=91.5;
Ci=(PCPY/91.5)*100;
Ti=[ (NTWA/NTW)/0.78 ]*100;
If Ti>=78 Then Ti=100;
Fi=(TA/120.5)*100;
Ni=Ci*Ti*Fi/10000;
Cards;

Proc Sort;
By YEAR;

Proc Means Noprint;
By YEAR;
Var Ni;
Output Out=New Ni=Total N=N;

Data B;
Merge A New;
By YEAR;
MPPI=Total/N;

Proc Sort;
By YEAR;

Data C Set;
Merge A New B;
By YEAR;
If First.YEAR;

Proc Print;
Var YEAR N Total MPPI;
```

Statistical Analysis

Mast data was collected from the Tennessee Wildlife Resources Agency and analyzed using a SAS (1982) program written to incorporate derived fruiting scalars for members of the white oak and red oak family. The Student's t-distribution was used in comparing serum and salivary estradiol levels for females observed in different conditions of estrus. Regression analysis was used to delineate relationships between mast values and observations of lactation during summer, winter and annually. Least-squares (LSMEAN) and analysis of variance (ANOVA) were used to analyze the relationship between den entry dates and the different reproductive cohorts. Since the seasonal data collected on urea, creatinine and U/C ratios could be considered neither dependent, or independent (Nelson 1984), a Scheffe's multiple comparison was used to test statistical differences between these variables. Den utilization was divided into regions within the study area and the G-test was used to compare den-use frequencies (Sokal and Rohlf 1981, In Wathen 1983:19). The 0.05 alpha level was used to determine statistical significance for all tests.

CHAPTER IV

RESULTS AND DISCUSSION

Trapping and Collaring

Trapping and radiocollaring of black bears within GSMNP was carried out from 15 June through 29 August 1984 and from 12 June to 19 August and 15 September through 18 November 1985. One thousand sixteen (1,016) trapnights were used to capture 64 individuals 69 times. Overall trapping success was 1 capture/14.7 trapnights. Thirty individual females were captured 35 times resulting in a female trapping efficiency of 1 capture/29.0 trapnights (Table 3). Ages of captured females ranged from 2.5 to 12.5 years ($\bar{X}$ = 5.9 years). This compares favorably with a reported average age of 6.4 years for 128 females trapped in the backcountry of GSMNP between 1972-1979 (Tri-State Black Bear Study 1983).

Eighteen (18) of 35 female bears (51.4%) were recaptures, 13, of which, were captured initially by previous researchers (72.2%). Female 609 was handled on 3 occasions, each time a recapture. The remaining individuals were initially trapped and became recaptures during this study (bears 710, 711 and 723). Twenty six (26) radiocollars were used on 24 individual females. After pulling her collar over her head, bear 711 was recaptured and recollared eight days after her initial collaring. Bear

Table 3. Summer and fall female trapping success by month and trapline in the northwest quadrant of GSMNP, Tennessee, 1984-1985.

Sugarland Mountain	15 June - 25 June '84	79	(3)	26.33
	12 June - 21 June '85	55	(1)	55.00
	15 Sept - 28 Sept '85[a]	102	(2)	51.00
Sugarland Mountain Subtotal		236	(6)	39.33
Bote Mountain	29 June - 11 July '84	91	(2)	45.50
	11 July - 24 July '85	96	(1)	96.00
	1 Oct - 12 Oct '85[a]	56	(0)	--
Defeat Ridge	18 July - 30 July '84	128	(4)	32.00
Upper Tremont	8 Aug - 16 Aug '84	37	(2)	18.50
	3 Nov - 18 Nov '85[a]	32	(0)	--
Bote Mountain Subtotal		440	(9)	48.88
Parson Branch Road[b]	25 July - 8 Aug '84	98	(2)	49.00
	25 Aug - 29 Aug '84	35	(1)	35.00
	16 July - 20 July '85	23	(2)	11.50
	9 Aug - 19 Aug '85	52	(6)	8.67
Parson Branch Road Subtotal		208	(11)	18.91

Table 3 (continued)

Trapline Location	Dates Operated	Trapnights (Female Captures)		Trapnights Per Female Capture
Turkeypen Ridge	4 Aug - 15 Aug '84	59	(3)	19.67
	22 June - 1 July '85	39	(3)	13.00
	29 July - 5 Aug '85	36	(3)	12.00
Turkeypen Ridge Subtotal		134	(9)	14.89
Study Area Total		1,016	(35)	29.03

[a]Fall trapping season
[b]Included Hannah Mountain and Bunker Hill Lead

710 was captured and collared both years of the study. Capture, tagging and radiocollar information are presented in Appendix C.

Fall Trapping

The fall trapping season of 15 September through 18 November 1985 was undertaken in an attempt to collect late season blood samples for urea nitrogen and creatinine analysis. One hundred ninety (190) of the total 1,016 trapnights were accumulated during this time and yet, the effort resulted in only 2 captures (1 capture/95.0 trapnights). No bear captures or trap visitations were recorded after 2 October.

Suspecting that fall trapping success might be low (Pelton pers. comm.), the usual trapline approach was abandoned and traps were placed selectively on portions of Bote and Sugarland Mountain where bear sign was observed. On two occasions, following snare placement, fresh bear scat and feeding sign (ie., the lapping of white oaks) was located within 5 m of baited traps, indicating that bears were both active in the area and reluctant to investigate baits. Despite a documented bear preference for fall foods high in carbohydrates and fats (Eagle and Pelton 1983, Grenfell and Brody 1983), sardines and table scraps were apparently unattractive to bears during this time. I attribute the extremely poor capture and visitation rate observed during the fall of 1985 to the abundant hard mast (ie., white oak and red oak acorns) produced within the study area. The bears responded by satiating themselves on acorns. Personal communications with bear researchers from Florida and Virginia revealed a similar drop in trapping activity during this time. Mast yields in these states were reported as good. Similarly, Erickson (1957) and Miller et al. (1973) found baits to be unattractive during periods of abundant "natural foods". Elowe (1987) found that bears in Massachusetts fed on certain fall foods to the exclusion of others available. Thus, it would seem, that seasonally, bears prefer natural foods over artificial foodstuffs (eg. trap baits) which are greater in carbohydrate and fat content. Reports of successful fall trapping for black bears are not common in the literature. Hellgren and Vaughan (1986), working in the Great Dismal Swamp, reported a capture on 26 October and Smith (1985), working in Arkansas, trapped a female during November despite an abundant overcup oak mast crop.

Evidence from this study, personal communication with other bear researchers and the lack of reported success in the literature all indicate that black bears are difficult to trap in the fall of the year. Trapability may increase if baits become attractive to bears during years of mast failure.

Trap Injuries

Observations of trap injury were made at all bear capture sites. Thirty (30) of 35 female captures (85.7%) resulted in injuries that were categorized as slight to none. Commonly, as noted by Johnson and Pelton (1980), there was a cable abrasion at the wrist and slight swelling of the paw. The remaining 5 female captures (14.3%) resulted in moderate injuries. Notably cuts and punctures of the toes and foot pads caused by the snare cable and cable clamps. These type injuries were typically observed on bears captured below the wrist. There were no severe trap injuries (broken bones and/or joint dislocations) observed on any female bears captured during this study, an attribute of the hood-spring modified foot snare (Johnson and Pelton 1980). Bears that were recaptured during the course of a single trapping session showed remarkably fast healing of previous wounds (pers. obs.).

During consecutive years of this study a trapped male was attacked by another bear (presumably male) and killed while in the snare. Both incidents occurred on Sugarland Mountain during late June. Attacks on trapped bears, while not frequent, are not uncommon in GSMNP (McLean pers. comm.) or in other parts of the bears' range. Numerous researchers have reported bear losses due to cannibalization (Jonkel and Cowan 1971, Kemp 1976, Payne 1978, Rogers 1987).

Collar Retention

Breakaway radio collars, as manufactured by Telonics, Inc. (Mesa, Arizona) had been experimented with by previous researchers working in GSMNP and the adjacent Pisgah National Forest (Wathen 1983, Carr 1983, Brody 1984). A combination of permanent static and breakaway collars were used during these studies. Subadult bears were generally fitted with breakaway collars and larger adult animals were given permanent static ones. In the summer of 1983, NPS personnel at GSMNP requested that breakaway transmitters be attached to all bears not just selected sex/age groups. Thus, breakaway radio collars, reinforced with vinyl electrical tape, were used exclusively during the two years of this study.

Of 27 radiocollars fitted to bears, 1 was never located (probable transmitter failure), 1 was cut off an illegally killed bear, 1 remained on a bear at the time of her harvest, 1 was removed by Georgia Game and Fish personnel, 2 were removed from bears for causing neck abrasions, 2 were intact when their transmitters expired, 4 remained intact and functioning at the end of this study and 15 of 27 collars (55.6%) deteriorated and/or were removed by bears during the study period (Table 4).

The length of the collaring period for females that dropped their collars ranged from 8 to 576 days ($\bar{X}$ = 335.7 days). A disparity in the length of retention of collars

Table 4. Fate of 27 radiocollars fitted to female bears in the northwest quadrant of GSMNP, Tennessee, 1984-1986.

Bear Tag#	Date Collared	Fate of Collar
702	17 June 1984	Collar deteriorated and broke free. Located 1/14/86
706	23 June 1984	Collar deteriorated and broke free. Located 1/11/86
653	5 July 1984	Collar deteriorated and broke free. Located 1/09/86
510	7 July 1984	Collar deteriorated and broke free. Located 2/01/86
711	21 July 1984	Collar removed by bear.
712	25 July 1984	Collar intact and functional at end of study.
550	26 July 1984	Collar deteriorated and broke free. Located 1/09/86
711	29 July 1984	Collar replaced. Transmitter expired December 1985
610	4 Aug 1984	Collar removed by bear. Located on 2/09/85
609	6 Aug 1984	Collar deteriorated and broke free. Located 8/12/85
709	6 Aug 1984	Radio contact lost for duration of study.
486	10 Aug 1984	Bear poached. Collar located Little River, Townsend, TN
717	14 Aug 1984	Transmitter expired December 1985.
718	15 Aug 1984	Collar deteriorated and broke free. Located 10/01/85
710	15 Aug 1984	Collar deteriorated and broke free. Located 7/31/85
737	27 Aug 1984	Collar removed by GA Game and Fish on 4/12/85.

Table 4 (continued)

Bear Tag#	Date Collared	Fate of Collar
520	24 Feb 1985	Winter collared. Collar broke free. Located on 2/01/86
722	20 June 1985	Collar intact and functional at end of study.
659	25 June 1985	Collar removed in den due to neck injury.
476	28 June 1985	Collar removed in den due to neck injury.
806	17 July 1985	Collar deteriorated and broke free. Located 1/13/86
808	18 July 1985	Collar intact and functional at end of study.
727	18 July 1985	Collar removed by bear. Located 1/01/86
710	31 July 1985	Collar deteriorated and broke free. Located 11/01/85
532	4 Aug 1985	Collar broke free in den. Located 2/16/86
429	12 Aug 1985	Collar on bear at time of harvest (12/07/85)
731	19 Aug 1985	Collar intact and functional at end of study.

was noted between years. Females collared in the summer of 1984 carried transmitters significantly longer ($P < 0.05$) than those bears collared in the 1985 season (394 days, N = 10 vs. 196 days, N = 5, respectively) (Table 5). This difference can be directly related to the availability of mast during the two years of the study. Bears collared in the summer of 1984 experienced a mast failure that fall. Females radiocollared in 1985 had abundant hard mast available to them (see Mast Indices). It is likely that the significant weight gain and associated increase in neck circumference of bears in 1985 led to early collar separation and/or collar removal. Observations from this study indicate that most bears were able to physically remove radiocollars that became tight. Wrapping the breakaway sections with electrical tape likely served to lengthen the collaring period for some individuals, however, its effectiveness was questionable. In two instances, electrical tape likely prohibited the timely breakaway of radiocollars. Females 476 and 659, in otherwise excellent condition and having produced cubs, suffered neck lacerations during the winter of 1986. These collars were removed and not replaced.

The decision to use breakaway collars often is followed by a search for a means of keeping them on bears longer. It is ironic that we spend time trying to modify a breakaway design to be more "permanent". Cotton webbing (Hellgren et

Table 5. An annual comparison of breakaway radiocollar retention (in days) for female bears captured and collared in GSMNP, Tennessee, 1984-1985.

Bear Tag#	Year Collared	Maximum Collaring Period	
702	1984	576	
510	1984	574	
706	1984	567	
653	1984	553	
550	1984	532	
718	1984	400	
609	1984	371	
710	1984	350	
610	1984	189	
711	1984	8	
520	1985	342	
532	1985	196	
806	1985	181	
727	1985	167	
710	1985	94	
TOTALS	1984 (N=10)	$\bar{X}$=394 days	$P<0.05$
	1985 (N=5)	$\bar{X}$=196 days	

al. 1988), electrical tape (this study), vegetable-tanned leather (Garshelis pers. comm.) and rubber inner tubing (Elowe 1987) have all been used to enhance or create breakaway designs. An alternative to modifying breakaway collars may be to attach permanent ones more loosely. Breakaway collars in this study, and in others (Hellgren et al. 1988) were fit snugly to the neck of the bear at the time of capture. Rogers (1987) attached permanent collars to bears by measuring collars to the widest part of the head and then securing them loosely to the neck. This technique may be the best way of minimizing neck injury while maintaining a number of radiotagged individuals.

The decision to use breakaway radiocollars within certain geographic regions can lead to considerable loss of data. Den inaccessibility (pers. obs., this study), winter movement (Hellgren and Vaughan 1986) and the extensive utilization of tree dens by bears in the southern Appalachians (Johnson 1978, Johnson and Pelton 1981, Lentz et al. 1981, Wathen 1983) can prevent the radiocollaring of bears on an annual basis. During this study (ie., the winter of 1985) 10 radiocollared females denned in trees and 4 others moved repeatedly. None of these individuals could be safely recollared. Annual recollaring may not present a problem in areas where bear dens are more easily accessed (Alt pers. comm.).

Mast Indices

Maximum Production Potential Index (MPPI)

Abundance of oak mast differed dramatically during the two years of this study. In 1984 white oaks within the Park and surrounding counties failed to produce acorns. Red oak production was average overall, but fruits were extremely localized (pers. obs.). The MPP indices for white and red oaks in 1984 were 8.74 and 19.99%, respectively. Acorns were abundant during the second year of the study (1985) and an excellent mast crop was observed for both oak groups. MPP indices were 33.31% for white oaks and 35.25% for red oaks.

MPP indices were calculated for a 10 year period from 1976 to 1985. White oak MPPI values ranged from a low of 8.74% in 1984 (the study's first year) to a high of 35.06% in 1985 (the second year of the study). The 10 year mean MPPI for white oaks was 21.04%. Red oak MPPI values ranged from 7.39% (1986) to 37.73% (1985) (10 year mean = 20.07). MPPI values for white, red and all oaks (ie. white and red oaks grouped together) are presented in Table 6 and Figures 4-6.

The fruiting behavior of oaks in the southern Appalachians can be summarized using calculated MPPIs and corresponding field observations of relative acorn abundance. Mast failures and poor conditions exist when

Table 6. White oak, red oak and total oak Maximum Production Potential Index values for Blount, Cocke, Greene, Sevier, Unicoi and Monroe counties, Tennessee, 1978-1988.

Year	White Oak		Red Oak		Total Oak	
	N	Index	N	Index	N	Index
1978	55	11.65	48	11.87	103	11.75
1979	106	18.60	79	19.73	185	19.08
1980	67	11.67	125	24.20	192	19.83
1981	107	22.38	89	18.80	196	20.75
1982	40	9.89	124	17.82	164	15.89
1983	81	22.74	63	11.86	144	17.98
1984	27	8.74	41	19.99	68	15.52
1985	124	35.06	134	37.73	258	36.45
1986	41	14.78	49	7.39	90	10.76
1987	73	14.28	89	15.98	162	15.21
1988	167	22.28	128	27.22	295	24.42

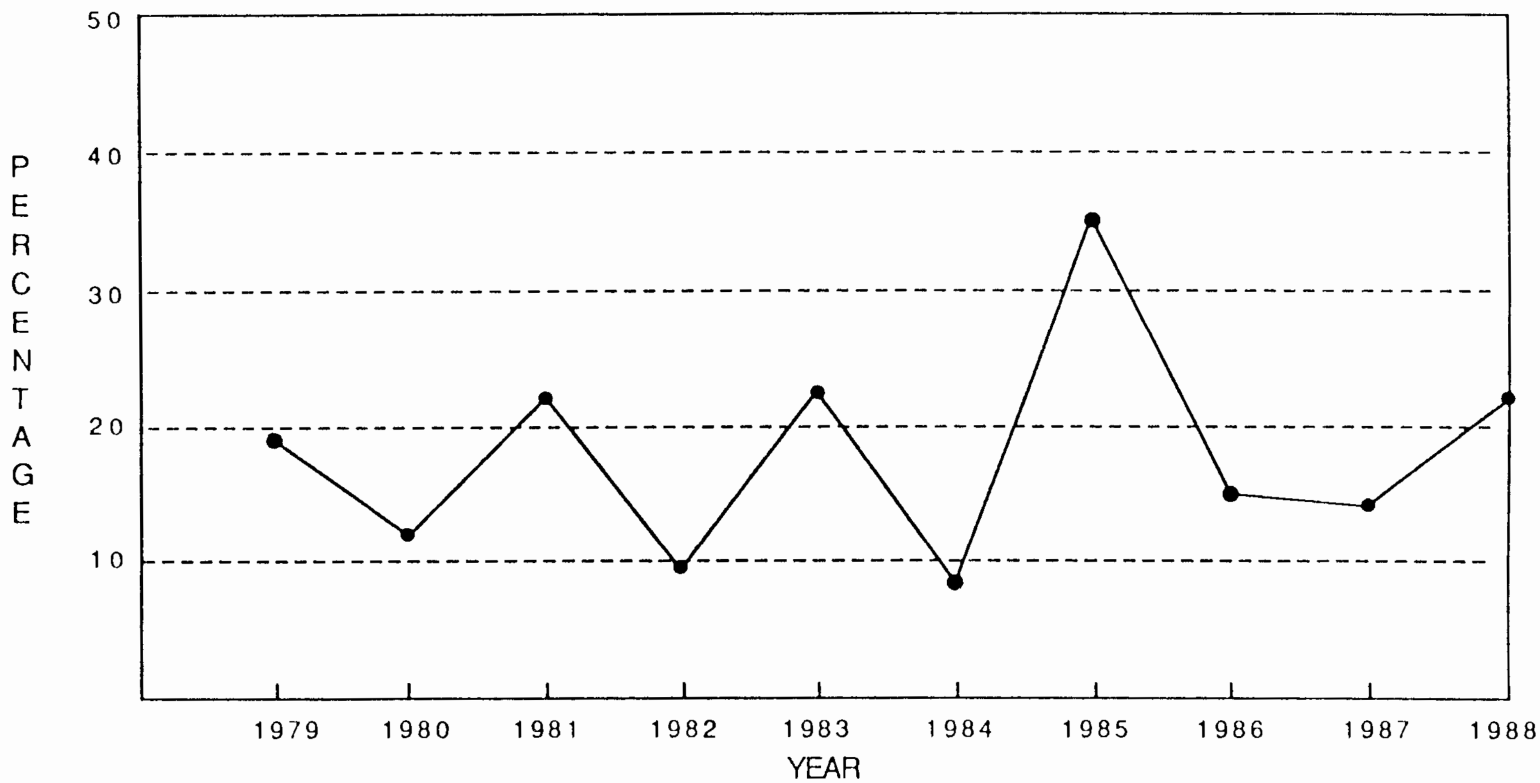

Figure 4. White oak Maximum Production Potential Indices calculated for Blount, Cocke, Greene, Sevier, Unicoi and Monroe counties, Tennessee, 1979-1988.

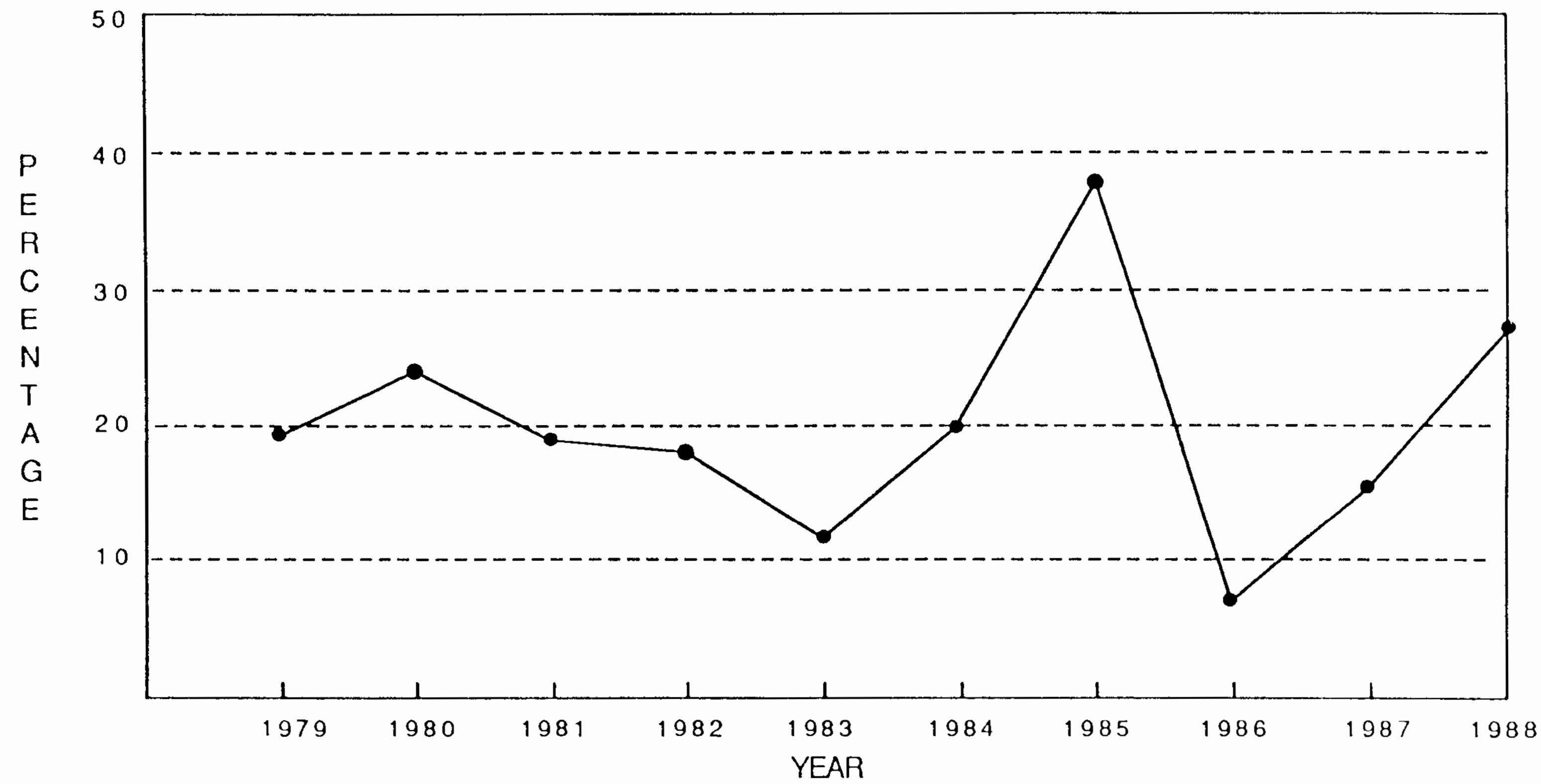

Figure 5. Red oak Maximum Production Potential Indices calculated for Blount, Cocke, Greene, Sevier, Unicoi and Monroe counties, Tennessee, 1979-1988.

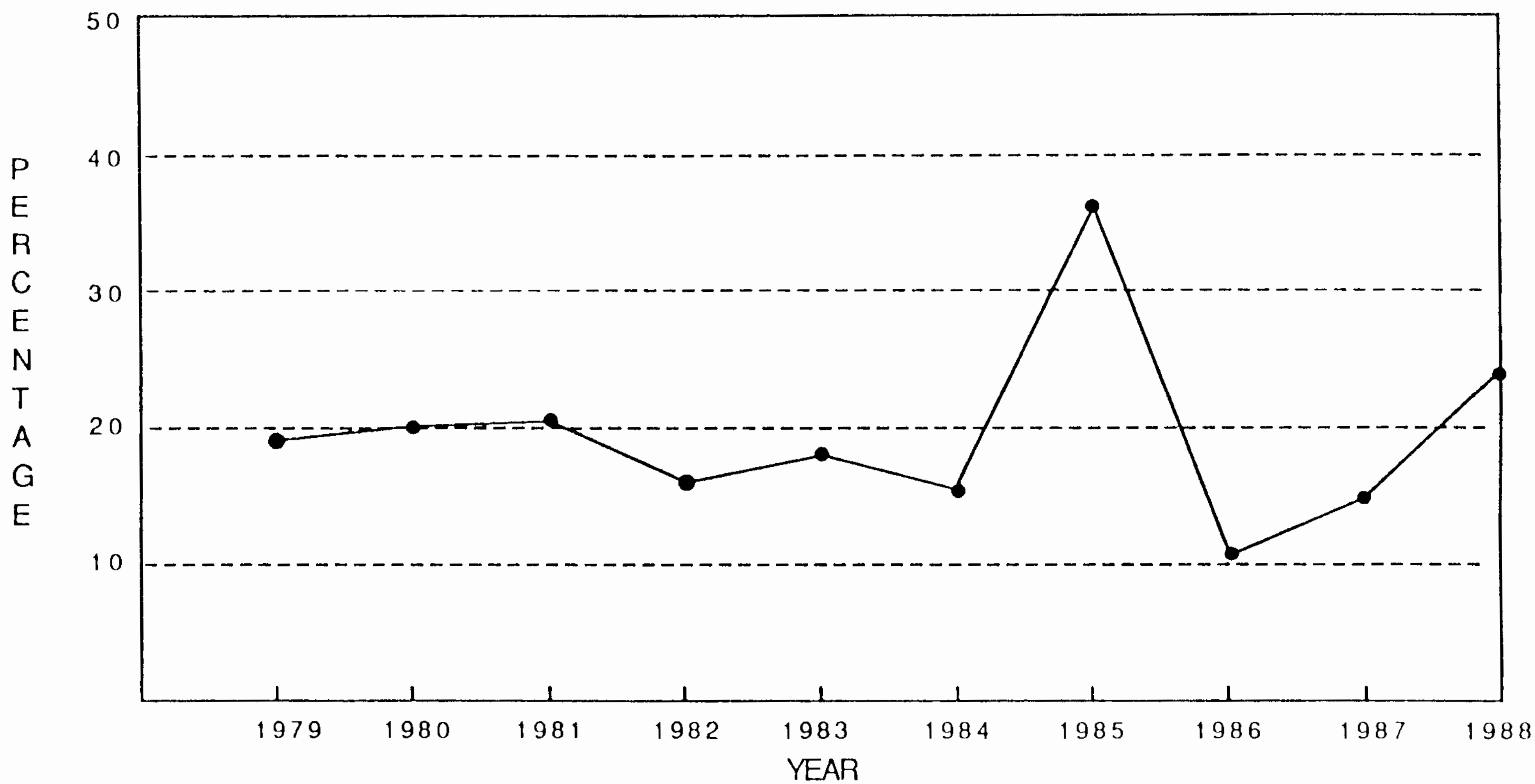

Figure 6. Combined oak (white and red) Maximum Production Potential Indices calculated for Blount, Cocke, Greene, Sevier, Unicoi and Monroe counties, Tennessee, 1979-1988.

abundance. Mast failures and poor conditions exist when oaks produce at $\leq$ 10% of their maximum fruiting potential. Average years occur when acorns are produced at 15 - 20% of maximum. Oaks bearing at 25 - 30% of their potential indicate an excellent mast crop and true "bumper" conditions exist when a MPPI of > 30% is reached (Fig. 7). Cumulative observations on the reproductive performance of bears within GSMNP indicate that the number of females producing cubs is severely limited when oaks produce at < 15% of their maximum ability. Females are affected, but less so, by MPPI values between 15 and 20%. Females expecting to birth their first litters (4 to 6 years old) may show a delay under these mast conditions. Reproduction is not affected when mast production is $\geq$ 25% of maximum.

Mast surveys can provide valuable long-term information on habitat productivtiy, and when coupled with harvest records may be used to delineate game population trends. State wildlife agencies currently collecting mast data should continue; those not should begin implementing such surveys. Ideally, mast data should be collected annually from standardized routes. Individual trees (determined to be inherent producers) should be marked and utilized every year. Several years of fruiting observations should be done to choose trees for sampling. Fruiting maximums should be calculated so that scalars can be used in the mathematical conversion to an index. Ultimately, mast data, obtained

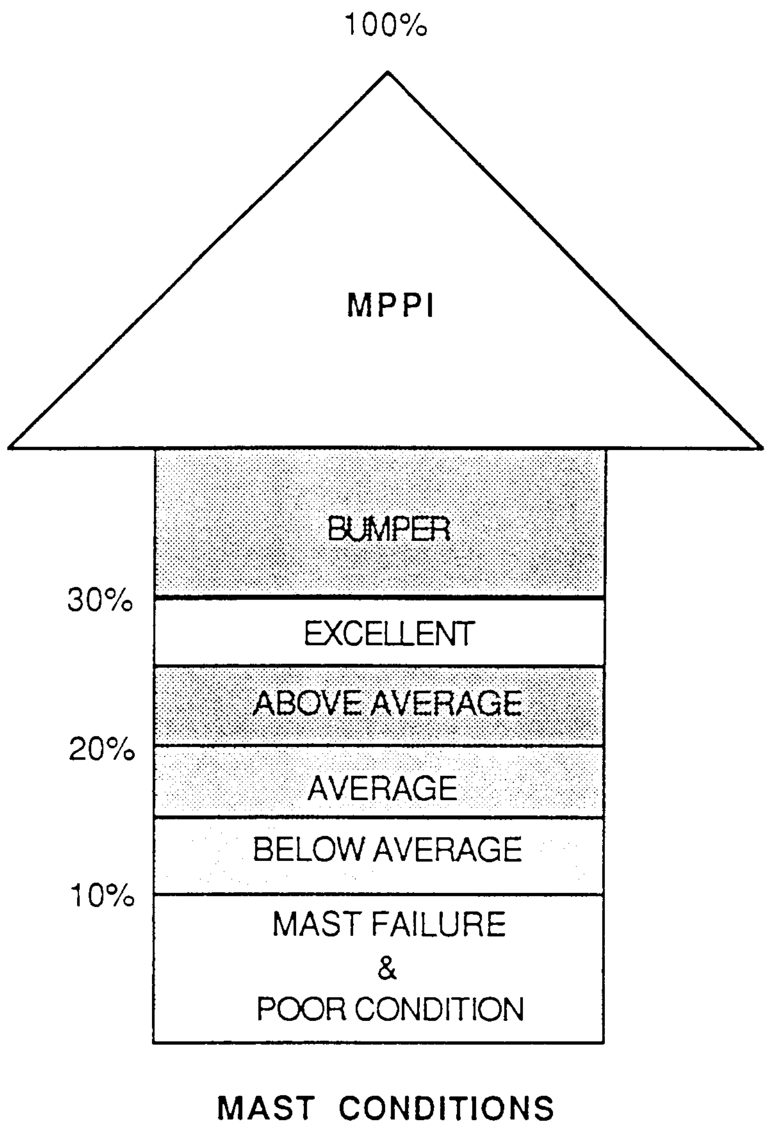

Figure 7. Maximum Production Potential Index interpretive scale for white oaks and red oaks in the Southern Appalachians.

from different species and within different regions, should allow for the creation of scaled indices which are directly comparable from region to region.

Annual Mortality

Six (6) of 35 collared bears died during this study (17.1%). Included in the total of radiotagged individuals were 7 females collared by a previous researcher (Keller, unpub. data) and 4 yearling bears (see Orphaned Cub Reintroductions in Appendix B). One of these radioed yearlings (715) had undergone extensive medical rehabilitation after being struck by a car. This bear died during the fall of 1985 (age 1.5 years) and was not used in calculating annual mortality rates. Minimum annual mortality rates during 1984 and 1985 were 8.8% and 5.9%, respectively. These figures are similar to others reported in the literature. Carney (1985) calculated a 95% survivorship for radio-tagged female bears in Shenandoah National Park and thus had a 5% annual mortality, and Hugie (1982), working in Maine, had an average 4% annual mortality amongst females.

Four (4) of 6 bear deaths in this study were human caused and 3 of these involved poaching. The fourth instance involved a questionable legal harvest of an 11 year old female (429) that was radio-tracked by plane and observed dead in the back of a truck. This occurred on the first day of Tennessee's 1985 bear season over the adjacent Cherokee National Forest. It was presumed the bear had been legally harvested. Despite the use of reward ear tags and collar plates identifying the University of Tennessee, I never received notification about the harvest of this bear. The last case of a collared bear mortality involved a 6 year old female (606). An initial den check on 4 January 1985 located this bear in a hemlock stump ground den. A second examination on 7 February 1985 found her freshly scavenged carcass 20 m from the den site. Heavy precipitation during the end of January (8" snowfall accompanied by 1.5" rain) may have prompted this female to leave her den, however the cause of her death remains unclear. This situation was complicated further by the discovery of skeletal yearling remains approximately 30 m from the dens' entrance. Decomposition of the carcass and tooth eruption within the mandible placed the time of death for this bear during the previous fall. Appropriately, according to unpublished data (Keller), female 606 should have been with yearlings that winter.

Reproductive Characteristics

Breeding Season and Observations of Estrus

Using vulval examination, 12 of 35 females (34.3%) were observed in estrus; 83% of these observations (10 of 12) occurred during a period from 20 June to 12 August 1984-85.

The latest observation of a bear in estrus was on 19 September 1985. Ages of estrus females ranged from 3.5 to 12.5 years.

Black bears are believed to be monoestrous (Jonkel and Cowan 1971, Rogers 1977) with a breeding season during June and July (Erickson and Nellor 1964). Rogers (1977) suggested "little geographic variation in the mating season of black bears", yet differences in the breeding period have been reported. New York has reported a breeding season from May to mid June (Wimsatt 1963). A majority of bears within GSMNP were observed to be in estrus from 24 June to 21 July (Eiler et al. 1989) and Smith (1985), working in Arkansas, reported a breeding season from mid July to mid August.

The timing of estrus in black bears may be affected by many factors. Rogers (1987) theorized that in harsh climates bears may complete breeding in a shorter time to optimize their foraging and fattening period. Jonkel and Cowan (1971) proposed variations in estrus based on the nutritional condition of the female and Eiler et al. (1989), working in the Great Smokies, concurred with their observations stating that "a poor hard mast crop the previous fall or a late berry crop during the summer may be sufficient to delay estrus for females in poor condition". Eiler et al. (1989) also reported that most observations of late estrus (ie., August and September) involved subadult females; bears which tend to be in poorer condition.

Observations from this study made during 1985 support the idea of a delayed estrus season for bears in a poor nutritional state. Following the mast failure of 1984, 41% of all estrus observations (5 of 12) were made after 1 August. However, no difference was detected between the mean age of females in estrus during June - July and August - September (6.7 years vs. 6.5 years, respectively). I believe that this is a reflection of the severity of the white oak mast failure in 1984. Wathen (1983) reported that bear productivity was almost always high following years of abundant white oak mast. Thus, the opposite condition is apparent. Low white oak production not only leads to low bear productivity but may also serve to alter the next seasons' estrous cycle. If the white oak failure is severe enough (eg., Fall 1984), resulting nutritional deficiencies may cause delayed estrus in both adult and subadult bears. The findings of this study and others within GSMNP and the adjacent Cherokee National Forest indicate that observations of late season estrus (August and September) are not uncommon in the southern Appalachians (Beeman 1975, Eiler 1981, Wathen 1983). These observations not only suggest an extension of the breeding period in the Southeast but also point to the nutritional inadequacies of the region.

While the breeding season may extend from June through August, individual periods of estrus for black bears are considered to be the shortest of any of the North American ursids (Rausch 1961). During this study, female 609 was captured on 12 August in estrus and recaptured 4 days later (16 August) in anestrus. Evidence from this observation supports the idea of a relatively short estrus period within the black bear. Rogers (1987) reported the maximum number of days that males were attracted to females as 5 and Wathen (1983) observed a change in the estrus condition for 2 females within 5 and 6 days of their respective recaptures.

The observation of a 4.5 year old female in estrus on 19 September 1985 represents the latest occurrence of estrus within this study area. This 34 kg (75 pound) female successfully bred that fall and bore her first litter (1 cub) in the winter of 1986.

Serum Estradiol

Observations of the vulva have been used to identify the condition of estrus in black bears. The technique, however, can be extremely subjective. The opportunity to examine the genitalia of individuals during varying stages of the reproductive cycle does not occur often under field conditions and thus, the experience of the observer becomes critical in correctly identifying the condition of estrus. Researchers during bear studies in the Great Smokies have attempted to detect and verify the condition of estrus using various means. Eiler (1981) used swelling of external genitalia, vaginal smears, vaginal pH and electrical resistance for determining estrus and anestrus conditions in GSMNP and CNF bears. Wathen (1983) continued reproductive research using visual examination of the vulva, vaginal smears and serum estradiol concentrations. Eiler (1981) concluded that vaginal pH and vaginal electrical resistance were not statistically capable of distinguishing between reproductive conditions. However, he found the presence and relative number of cornified epithelial cells within vaginal smears could be used in identifying a sexually attractive female. Wathen (1983) found vaginal smears unreliable in determining estrus but concluded that females observed in estrus (subjectively) had significantly higher levels of estradiol ($P < 0.001$) than females showing no signs of estrus.

Paired data (ie., blood samples with visual examination of the vulva) were collected from 31 females trapped during 1984 and 1985. Females that were subjectively determined to be in estrus (swollen vulvas, $N = 12$) had significantly lower levels of estradiol ($P < 0.005$) than females that showed no signs of estrus ($N = 19$) ($\bar{X} = 11.06$ pg/ml vs. $\bar{X} = 25.44$ pg/ml, respectively. Table 7). Female 609, the 5.5 year old handled twice within 4 days, was in estrus on 12 August. On 16 August signs of her estrus had ended. Serum analyses from each capture revealed estradiol levels of 1.96 pg/ml (pronounced vulval swelling, bear in estrus) and 49.58

pg/ml (no swelling, bear in anestrus), respectively. These findings contradict those of Wathen (1983).

Reliable information on the activity and blood level of steroid hormones involved with the estrous cycle do not exist for the black bear (Foresman and Daniel 1983). However, detailed information does exist on hormonal functions in domestic livestock. The estrous cycle of the domestic ewe typifies that of most mammals (Hafez 1980: 103). Control of the cycle depends on the interaction of follicle stimulating hormone (FSH), leutinizing hormone (LH), estrogen (ie., estradiol-17B) and progesterone. During the follicular phase of the cycle (pre-estrus), progesterone rapidly declines while estradiol-17B peaks. The result is the beginning of estrus. Throughout estrus blood levels of estradiol decline. The return of estradiol levels to those approximating the follicular phase occurs at ovulation (Fig. 8). If conditions within the estrus ewe are comparable to those within the black bear, it is possible that the elevated serum estradiol levels found by Wathen (1983) were taken from bears just entering estrus (pre-ovulatory); estradiol levels would be at their peak during this time. Conversely, the significantly lower estradiol level of females in estrus found during this study could have been obtained from females in the waning stages of estrus (post-ovulatory). Given that ovulation in black bears is induced by coital stimulation (Wimsatt 1963,

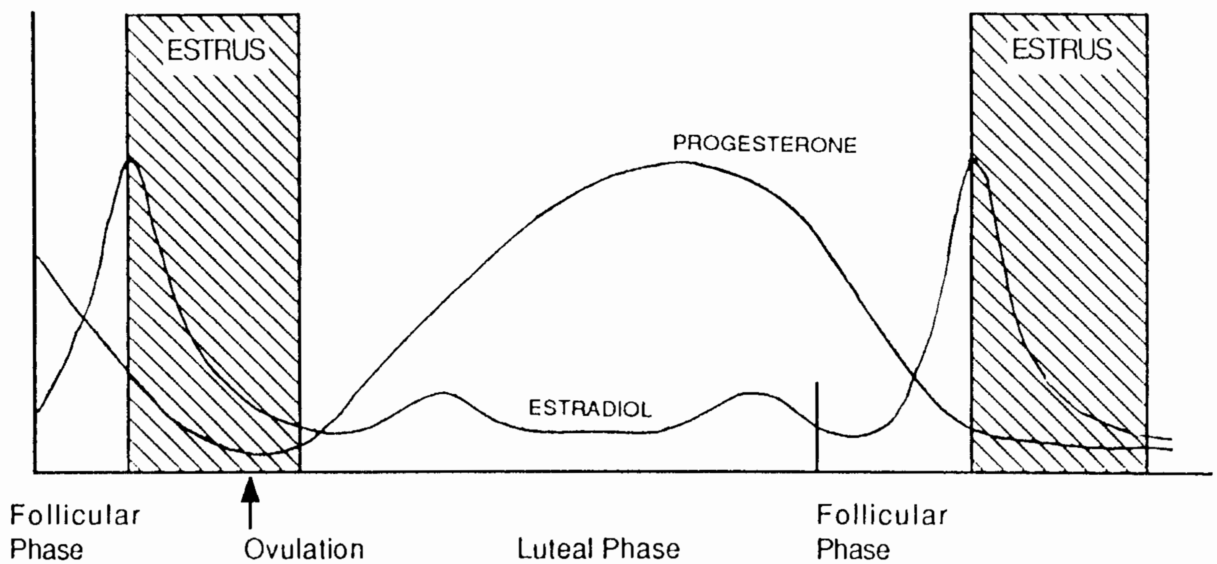

Figure 8. Blood levels of steroidal hormones in the domestic ewe.

Erickson and Nellor 1964) those estrus individuals observed by Wathen (1983) probably had not yet bred, while those in estrus during this study had. Previous discussion concerning the relatively short duration of estrus in black bears would seem to make this unlikely, however, supportive evidence for such an occurrence does exist. Ammons (1974) and Rogers (1987) observed periods of male to female attractiveness just prior to (and after) the period of female receptivity. Thus, attracted male bears may "check" (eg., by scent-trailing) the reproductive condition of estrus females and remain in their area until they become receptive (Rogers 1987). Once a female has allowed breeding to occur, males likely disperse into adjacent female territories in search of subsequent mating opportunities. The result could be concentrations of relatively sedentary males in areas where females are sexually attractive but not yet receptive. Trapping such an area could result in a large percentage of male captures (Wathen 1983). On the other hand, males may continually move in an area containing a number of females in the receptive stage. Capture sex ratios would likely approach 1:1 while trapping during such a period of frenzied bear activity. Accordingly, Wathen (1983) reported capturing a greater proportion of males (9 of 11 captures) during the 1981 breeding season in GSMNP (a result of a number of females in the "attractive " stage of estrus). No such predominance of male captures occurred during the breeding seasons observed in this study (a concentration of females in the "receptive" stage of estrus).

Despite conflicting results of the estradiol blood levels from estrus and anestrus bears noted between this study and that of Wathen (1983), estradiol may still be useful in verifying the estrus condition of black bears. Evidence from this study suggests that estradiol levels may not only be useful in identifying estrus, but may be capable of identifying pre and post-ovulatory females. Information is still needed on baseline levels of estradiol within black bears (as suggested by Wathen 1983). The study of captive females would allow monitoring of steroidal hormones throughout the estrous cycle. Additionally, observations of the external genitalia during the cycle could allow for the development of a "receptivity key" capable of identifying the various phases of estrous. Such a key, utilizing the degree of swelling and coloration of the vulva, is currently used by commercial rabbit producers to identify the period of peak receptivity in breeding does (McNitt pers. comm.).

Salivary Estradiol

Saliva samples (N = 13) were successfully collected from black bears during the 1985 trapping season using the technique of Pozzanghera et al. (1986). Paired saliva/blood samples were obtained for 11 females. Salivary estradiol levels for females observed in estrus (N = 6) ranged from 1.88 pg/ml to 16.80 pg/ml ($\bar{X}$ = 10.12 pg/ml). Estradiol levels in saliva of anestrus females (N = 5) ranged from 9.80 pg/ml to 17.80 pg/ml ($\bar{X}$ = 13.80 pg/ml). Values were consistent with those from serum samples in that mean estradiol levels for females in estrus were lower than those from anestrus females (Table 7), however, this difference was not significant ($P > 0.2$). Saliva and blood collections should continue to further investigate the relationship between estradiol level and the detection/verification of the estrus condition.

Lactation

Seven (7), of 29 bears $\geq$ 3.5 years old (potential nursing females) captured during 1984-85 were lactating (24.1%). Ages of lactating females ranged from 4.5 to 12.5 years ($\bar{X}$ = 7.6 years). Most observations of lactation (5 of 7, 71.4%) involved females $\geq$ 7.5 years (Table 8). Cubs of lactating females were observed at 4 trap sites. However, cubs were not found in the vicinity of 2 lactating females trapped in July and August 1984. It was presumed that the cubs were close by but not observed. However, neither one of these females was found to be with yearlings when examined in their dens in 1985 which likely indicates the loss of two litters. The severity of the mast failure of

Table 7. Mean and standard deviation of serum and salivary estradiol-17B concentrations (pg/ml) for female bears captured in the estrus and anestrus condition, GSMNP, Tennessee, 1984-1985.

Medium Tested/Reproductive Status		Estradiol-17B Concentration (pg/ml)			
		N	$\bar{X}$	SD	
Serum:	Females in estrus	12	11.06	11.38	P<0.005
	Females in anestrus	19	25.44	13.64	
Saliva:	Females in estrus	6	10.12	5.06	P>0.2
	Females in anestrus	5	13.80	3.70	

Table 8. Teat measurements, observations on lactation and presence or absence of offspring at capture sites for female bears captured in GSMNP, Tennessee, 1984-1985.

Bear Tag#	Capture Age	Teat Size W (mm)	Teat Size L (mm)	Was[1] or had[2] Lactated (No)	Was[1] or had[2] Lactated (Yes)	Observation of Offspring at Site
703	2.5	3	2	N		
730	2.5	3	3	N		
723	2.5	4	3	N		
702	3.5	4	3	N		
722	3.5	3	4	N		
806	3.5	4	3	N		
611	4.5	4	4	N		
731	4.5	5	4	N		
718	4.5	11	10		Y[1]	With at least 1 cub
609	4.5	6	5	N		
813	4.5	5	4	N		
706	4.5	3	3	N		
808	5.5	5	5	N		
532	5.5	5	8	N		
609	5.5	8	7	N		
712	6.5	10	10		Y[2]	
710	6.5	10	11		Y[2]	
653	6.5	9	7	?	?	

Table 8 (continued)

Bear Tag#	Capture Age	Teat Size W (mm)	Teat Size L (mm)	Was[1] or had[2] Lactated (No)	Was[1] or had[2] Lactated (Yes)	Observation of Offspring at Site
659	6.5	10	11		Y[2]	
550	7.5	12	15		Y[2]	
709	7.5	18	22		Y[1]	With 2 cubs
710	7.5	9	8		Y[2]	
711	7.5	12	12		Y[1]	No cubs observed
717	7.5	6	8		Y[1]	No cubs observed
814	7.5	11	20		Y[2]	
486	8.5	16	21		Y[2]	
737	8.5	15	29		Y[1]	With at least 2 cubs
429	10.5	12	27		Y[2]	
476	12.5	15	25		Y[1]	With 2 yearlings
727	?	8	13		Y[2]	

1984 was evidenced by the scarcity of females lactating during the following summer. Of the 7 observations I made of lactation, only 1 occurred in 1985 (Fig. 9) and this instance was unusual. Female 476 was captured on 28 June 1985 in the Turkeypen Ridge section of the study area. She was lactating, but was found with 2 yearlings, not cubs. Later during the work-up it was discovered that the female was also in estrus (this observation was later confirmed by estradiol analysis). She was subsequently observed in her den in 1986 with 2 newborn cubs. The observation of a lactating, estrus female with yearlings raises some interesting questions. Generally, weaning of black bear cubs is considered to occur 5 to 7 months post-partum (Rausch 1961, Jonkel and Cowan 1971, Wathen 1983, Elowe 1987) and nursing is considered to be the stimulus which inhibits a female from entering heat. Recently, LeCount (1983) and Alt (pers. comm.) observed females raising cubs in successive years. As speculated by Wathen (1983:51), this could occur if a female weaned her cubs prior to the end of the breeding season. In the case of female 476, a possible scenario is one in which I observed the yearlings just prior to family break-up and failed to detect her weaned cubs of the year. She bred while in estrus and produced cubs in 1986. Since there were no yearlings in the den, one might speculate that they had denned elsewhere (LeCount 1980). While this observation is certainly

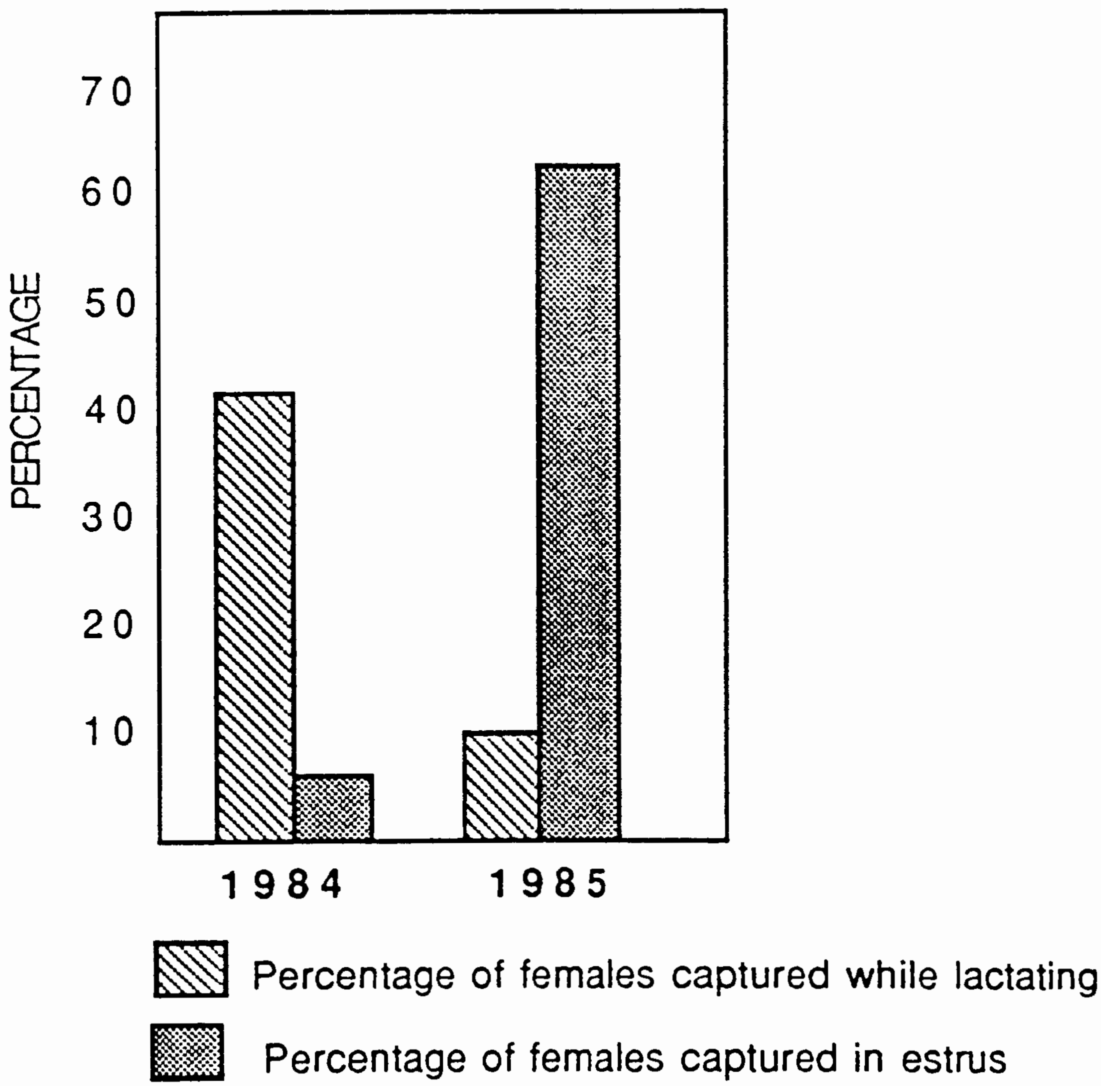

Figure 9. An annual comparison of the percentage of female black bears captured while lactating vs. those captured in estrus in GSMNP, Tennessee, 1984-1985.

noteworthy, I agree with Eiler et al. (1989) that such occurrences in the southern Appalachians are uncommon and as such should not be considered a factor in the reproductive performance of this population.

Numerous researchers have shown a relationship between the observation of cubs or lactating females and the yields of mast from the previous fall (Eiler et al. 1989, Elowe 1987, Wathen 1983, Reynolds and Beecham 1980, Rogers 1976). Wathen (1983:61) used regression analysis to examine this relationship between bear productivity and fall hard mast within the GSMNP. While he was able to report linear associations between white oak mast and the percentage of females lactating or with young, the values were not statistically significant (likely due to limited data). I compiled GSMNP reproductive data from 1979 to 1988 to expand on and support the findings of Eiler (1981) and Wathen (1983).

Maximum production potential indices (MPPI'^{S}) and the percentage of females observed lactating (by season) are shown in Figs. 10-12. Regression analysis showed a statistically significant linear relationship between the white oak mast crop and the number of lactating females in winter (R2=0.69, P<0.003), summer (R2=0.45, P<0.03) and on an annual basis (R2=0.62, P<0.007) (Table 9). Red oak mast was not related to the percentage of females observed lactating during any season (All P values < 0.36). Total

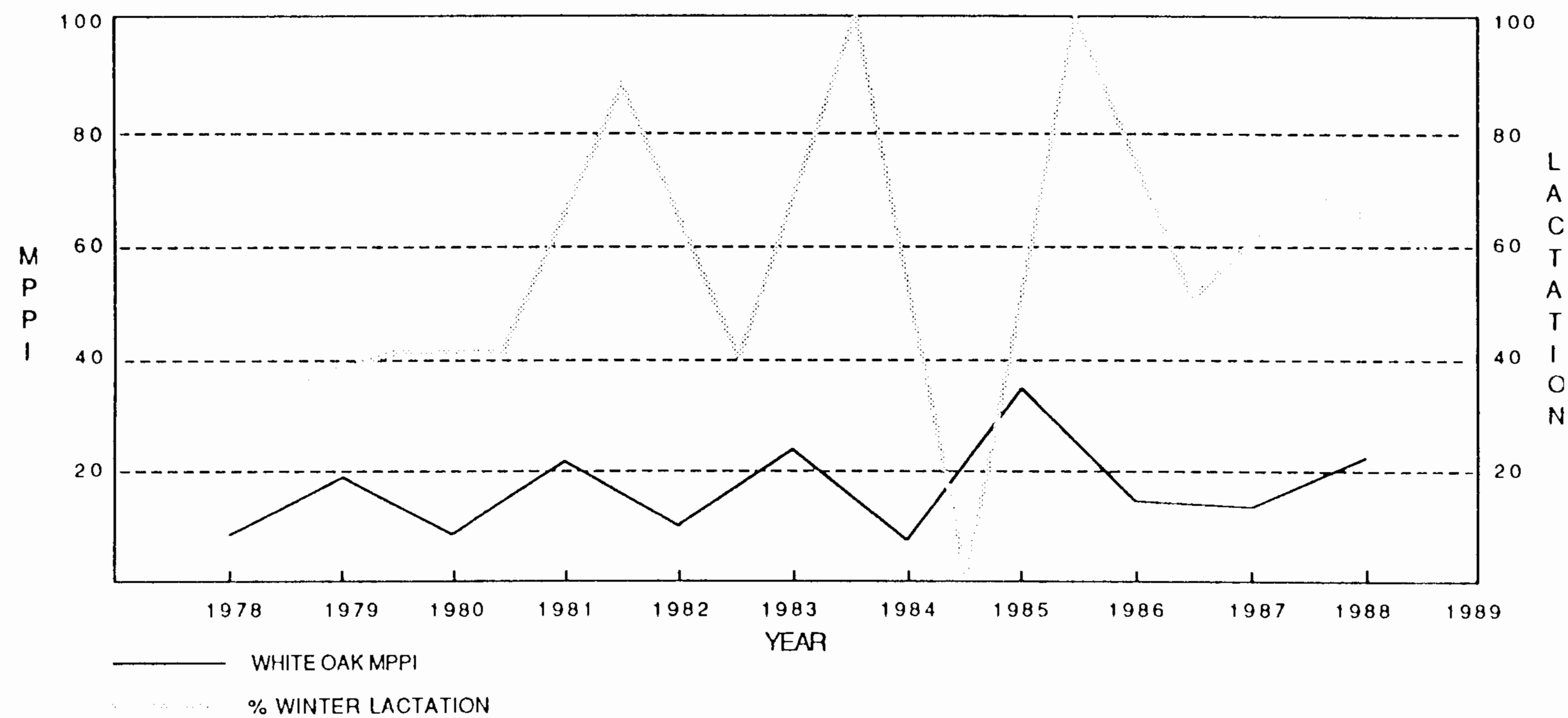

Figure 10. White oak Maximum Production Potential Indices and the percentage of winter lactating bears observed in GSMNP, Tennessee, 1979-1989.

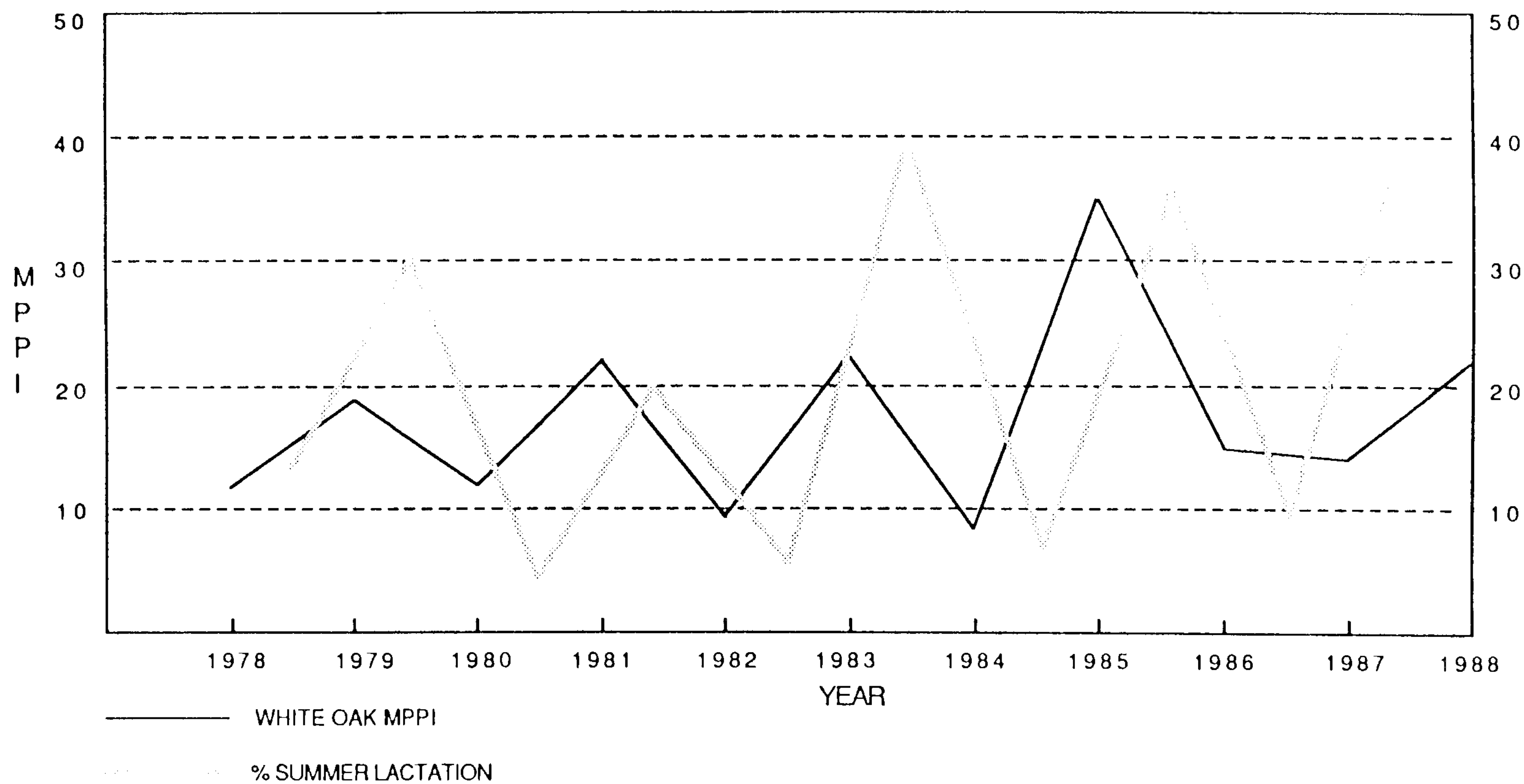

Figure 11. White oak Maximum Production Potential Indices and the percentage of summer lactating bears observed in GSMNP, Tennessee, 1979-1989.

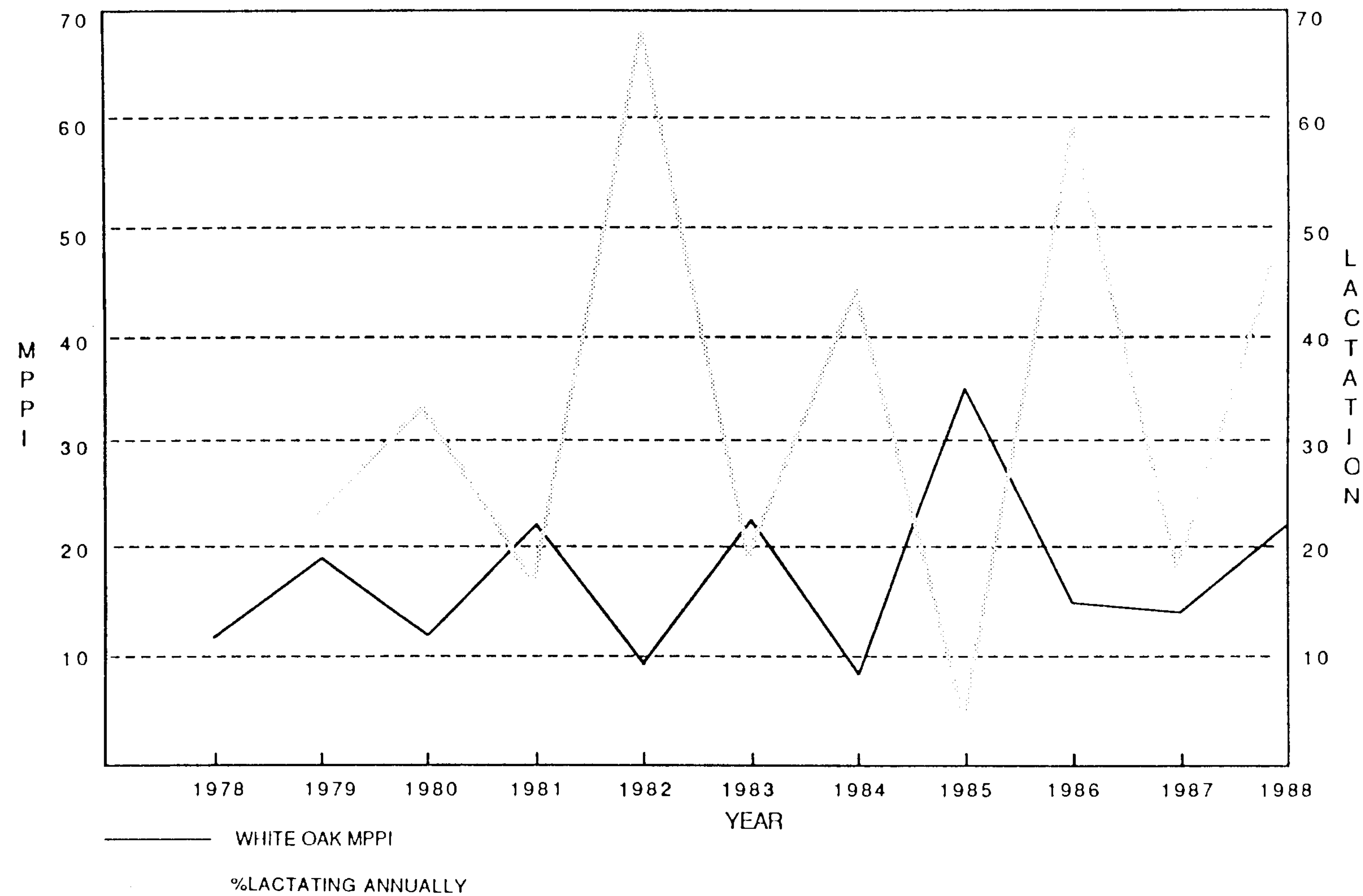

Figure 12. White oak Maximum Production Potential Indices and the percentage of bears observed lactating annually in GSMNP, Tennessee, 1979-1989.

Table 9. Regression analysis between white, red and combined oak mast MPPIs and the percentage of females lactating in winter, summer and annually in Great Smoky Mountains National Park, 1978-88.

Season Observed Lactating	Mast Type	R^2	Probability (P <)
Winter	White Oak	0.69	0.003*
	Red Oak	0.05	0.53
	All Oak	0.30	0.10
Summer	White Oak	0.45	0.03*
	Red Oak	0.04	0.61
	All Oak	0.18	0.22
Annually (Comb. Seasons)	White Oak	0.62	0.007*
	Red Oak	0.10	0.36
	All Oak	0.32	0.08

*Denotes statistical significance at 0.05 level.

oak mast (white and red oaks combined) was linearly related, though not significantly, to the percentage of females lactating annually (R2=0.32, P<0.08). These results, derived from 10 years of mast and reproductive data in GSMNP, support and lend statistical validity to previous findings in the southern Appalachians (Wathen 1983). White oak mast is critical to black bear productivity in this region and during the years of white oak failure, red oak seems to offer little compensation.

The percentage of lactating females captured in the summer as related to the previous fall's mast was the weakest of the significant relationships (R^2=0.45, P<0.03). One possible explanation for this is early weaning during the trapping season coupled with the failure to detect cubs at trap sites. If females enter dens in good nutritional condition following an abundant mast crop they could theoretically wean their cubs at an earlier age due to the production of large quantities of high quality milk (Jenness 1985 in Elowe 1987:21). Spring is considered a negative foraging period for bears within GSMNP (Poelker and Hartwell 1973). In some years early warming and high precipitation may speed plant development and make herbaceous material available to bears sooner than usual. Cubs have been known to begin feeding on plant material as soon as the first week of May (Elowe 1987). Therefore, early weaning, due to excellent winter condition of maternal females or early ingestion of spring foods by cubs, may decrease the number of lactating females reported during a June to September trapping season.

Minimum Reproductive Age

Minimum reproductive age as revealed by summer teat examination, observation of offspring at capture sites, and winter den observations was determined for 5 females during 1984-85. The mean age for a female at the birth of her first litter was 5.2 years (range from 4 to 6 years) (Table 10). One female captured at the age of 4.5 years was with cubs. While this female could not be used in determining minimum reproductive age it can be stated that she successfully bred at $\leq$ 4 years. Using teat measurements and examination I had no indication, from 3, 2.5 year olds or 3, 3.5 year olds, of birthing success at ages 2 or 3, respectively. While based on a limited number of observations, the minimum reproductive age calculated for this study is slightly higher, yet consistent, with the findings of Eiler et al. (1989) who compiled data from the GSMNP and adjacent Cherokee National Forest and reported a mean minimum reproductive age of 4.6 years.

Numerous studies have reported on the breeding of black bears at the age of 2.5 years (Raybourne 1976, Eiler 1981, Graber 1981, Collins 1985) and Pennsylvania has been able to document breeding of a 1.5 year old (G. Alt, pers. comm.).

Table 10. Minimum reproductive age determined for female black bears in GSMNP, Tennessee, 1984-1986.

Bear Tag#	Portion of Study Area	Year of First Litter	Age at First Litter
610	Parson Branch Rd.	1984	5
722	Turkeypen Ridge	1986	4
532	Turkeypen Ridge	1986	6
731	Sugarland Mt.	1986	5
808	Parson Branch Rd.	1986	6

As suggested by Eiler et al. (1989) the breeding of these subadults is of little value in the southern Appalachians where only 5% of 3 year olds were found with cubs. I believe there has been some misunderstanding of the reproductive performance of bears in the Southeast. Corpora luteal counts indicate only breeding activity and do not reflect birthing success (Tri-State Black Bear Study 1983:14-26). While minimum breeding age may be 2.5 years, the majority of females do not contribute cubs to the population until they are 4 to 6 years old.

Evidence for poor nutrition delaying the minimum reproductive age of females was gathered during this study. One 4 year old, 2, 5 year olds and 1, 6 year old expected to produce their first litters failed to do so following the mast failure of 1984. In addition reproductive skips were noted for 1, 7 year old and 1, 8 year old. Conversely, after the bumper mast crop of 1985 all females in the 4 to 6 year old age class produced cubs (N = 3) and no reproductive skips were observed. Jonkel and Cowan (1971), Rogers (1976), Beecham (1980) and Eiler et al. (1989) have all documented the role of nutrition on the reproductive fitness of female bears. In the southern Appalachians, alternate, reliable food sources (ie., agricultural crops and garbage dumps) are not readily available to bears. As a result, reproductive performance may vary greatly from year to year.

Denning

Entrance Dates

Den entrance dates were obtained for 20 radiocollared females. Entrance date accuracy ranged from 3 to 8 days. Females entered dens from 5 December to 15 December during the winter of 1984-85 and from 27 November to 30 December during the winter of 1985-86 (Table 11). The difference in den entry between years was not significant. The majority of females (18/20, 90%) entered dens during the first half of December. Only 2 denned outside of this period. One female entered a shallow ground nest on 27 November and a second delayed den entry until 30 December. An 18 year old female failed to enter a den during the winter of 1984-85. Mean dates of den entry for bears of varying reproductive conditions were 7, 10 and 12 December for females with yearlings, females without young and pregnant females, respectively. Analysis of variance and LSMEAN analysis showed no statistical difference between the date of den entry and the reproductive status or denning location (tree or ground) of a female ($F=0.21$, $P<0.82$ and all P values < 0.38).

Den entrance dates reported here are consistent with those found in earlier studies within the Park. Eiler (1981) found most GSMNP females entering dens during the first 3 weeks of December and Wathen (1983) reported a mean entry date of 20 December for this study area. Numerous

Table 11. Mean den entrance dates for females without offspring, females with newborn cubs and females with yearlings, GSMNP, Tennessee, 1984-1986.

Reproductive Status of Female	Range and Mean Dates of Den Entrance	Comments
Females Without Offspring (N = 10)	5 Dec - 15 Dec $\bar{X}$ = 10 December	Observations Winter '84-85
Females With Newborn Cubs (N = 6)	27 Nov - 30 Dec $\bar{X}$ = 12 December	Observations Winter '85-86
Females With Yearlings (N = 4)	No Range $\bar{X}$ = 7 December	Observations Winter '84-85

studies have documented similar patterns of den entry for females of varying reproductive condition (Eiler 1981, Wathen 1983, Carney 1985, Smith 1985). Generally, pregnant females are the first to enter dens, followed by barren females and females with cubs of the year ("coys"). During this study, pregnant females (N = 6) entered dens an average of 4 days after the other 2 groups. I believe this discrepancy is related to an unequal annual representation of the different reproductive cohorts and to food availability. Barren females (N = 10) and females with yearlings (N = 4) comprised the entire sample following the mast failure of 1984. All females were pregnant after the "bumper" mast crop of 1985. Thus, an interpretation of the role of reproductive status on den entry during this study was complicated by food availability.

Food availability as an influence on the timing of den entry has been a controversial topic. Within the GSMNP Johnson and Pelton (1980) reported bears entered dens earlier in years of mast scarcity. Eiler (1981) found no relationship between fall food abundance and entrance dates and Wathen (1983) reported a majority of pregnant females entered dens earlier in a good mast year. During this study females denned earlier ($\bar{X}$ = 10 December) in the winter of 1984-85 (mast failure) than in 1985-86 ($\bar{X}$ = 12 December, bumper mast crop). Females also entered dens in a shorter time period during the winter of scarce food (11 days) than in the winter of abundant food (34 days). In two instances during 1985-86, females were located by air at their eventual den locations and then made short foraging journeys away from the sites before returning to den. Observations from this study support the findings of Jonkel and Cowan (1971), Johnson (1978), O'Pezio et al. (1983) and Smith (1985) that black bears delay denning during years of abundant mast. Also, if mast conditions are unusually favorable (eg. fall 1985 in GSMNP), food abundance may overide the affect of reproductive status on the timing of den entry.

Den Utilization

All females observed (N=12) denned in trees during the winter of 1984-85. Conversely, a predominance of ground denning took place (5 of 6 females) during the winter of 1985-86.

Wathen (1983) observed a similar pattern of den selection within the GSMNP and theorized that such anomalous behavior was due to physical condition of females. Following excellent fall mast crops, bears are considerably heavier and their size may restrict them from entering tree dens. My observations support the theory of Wathen. The fall of 1985 was the best white oak mast crop observed in over a decade and 5 of 6 females denned on the ground. The only instance of a female denning in a tree involved a large yellow poplar.

To expand on the work of Wathen (1983), I compiled den utilization data, with respect to major portions of the study area for adult females observed in dens in GSMNP from 1978 to 1986. Of additional interest was the birthing location for cubs (ie., either tree den or ground) and the denning behavior of adult females with yearlings.

Seventy-two den sites, for 27 adult individuals were observed from 1978 to 1986. Tree dens (N=42) accounted for 58.3% and ground dens (N=30) represented 41.7% of all observations. Denning behavior differed within portions of the study area. Bote Mountain and Parson Branch Road were predominantly tree denning areas (61.1% and 93.3%, respectively), while Sugarland Mountain females denned on the ground 71.4% of the time (Table 12).

The extensive utilization of tree dens by black bears has been well documented by researchers within GSMNP (Pelton et al. 1980, Eiler 1981, Johnson and Pelton 1981, Wathen 1983) and the security and thermal efficiency afforded by such trees (Johnson 1978) make them valuable assets to any bear population. The fact that tree den utilization is higher (58.3% vs. 41.7%, respectively) than ground den utilization within the GSMNP suggests a denning preference. However, when I examined birthing location for 29 litters, 16 (55.2%) were born to females denned on the ground.

Table 12. Tree denning and ground denning behavior of adult female black bears in GSMNP, Tennessee, 1978-1986.

Section of Study Area	No. of Dens	No. Bears (Individuals)	Den Type Used Tree	Den Type Used Ground
Bote Mt./Turkeypen	36	13	22	14
Sugarland Mt.	21	9	6	15
Parson Branch Rd.	15	5	14	1
Totals	72	27	42	30

Females with yearlings denned on the ground 36.8% of the time (7 of 19 observations) (Table 13). As speculated on previously, nutrition likely accounts for this behavior. Females in good condition are those most likely to have cubs; yet their size may prevent them from being physically able to enter tree dens. Ground dens as well as tree dens are critical to the reproductive performance and recruitment of a bear population. Forest management in areas where bears exist should include both the preservation of old growth and maintenance of suitable ground denning habitats.

Den Reuse

Twelve tree dens and 1 ground den were examined and tagged during winter 1985. In 1986 repeat visits were made to 10 of those 12 trees, 1 additional tree den was examined and 6 ground dens were visited (1 from 1985 and 5 new dens used by females that winter). Den tree characteristics and tagging information are presented in Table 14. No reuse of tree dens and only 1 case of ground den reuse was observed. Female 606 used the same ground den (a hemlock stump) in 1985 that she had used in 1983 (Keller pers. comm.).

The reuse of dens by black bears has been investigated by numerous researchers; yet there seems to be no general agreement on, or pattern to, this behavior. Alt and Gruttadauria (1984) theorized on a possible inverse relationship between den reuse and availability and reported

Table 13. Observations of females with cubs and females with yearlings (yrlngs.) *vs.* den type utilized in GSMNP, Tennessee, 1978-1986.

Section of Study Area	Females with Cubs (Ground)	Females with Cubs (Tree)	Females with Yrlngs (Ground)	Females with Yrlngs (Tree)
Bote Mt/Turkeypen	14		5	
	(8)	(6)	(2)	(3)
Sugarland Mt.	9		7	
	(7)	(2)	(5)	(2)
Parson Branch Rd.	6		7	
	(1)	(5)	(0)	(7)
Totals	29		19	
	(16)	(13)	(7)	(12)

Table 14. Tagging information and characteristics of 13 den trees examined in GSMNP, Tennessee, 1984-1986.

Section of Study Area	Den Tree Species	Forest Type	Tree Tag No.	Date Tree Tagged	Height to Cavity (m)
Sugarlands	Yellow Poplar	Cove Hardwood	85-1	2/02/85	18.7
Sugarlands	N. Red Oak	Closed Oak	85-2	1/07/85	12.8
Sugarlands	Sugar Maple	N. Hardwood	85-3	1/09/85	13.9
Turkeypen	Chestnut Oak	Closed Oak	85-4	1/09/85	9.0
Bote Mt.	Black Cherry	N. Hardwood	85-5	1/11/85	9.2
Elkmont	Car. Silverbell	Hemlock	85-6	2/03/85	14.5
PBR*	N. Red Oak	Open Oak/Pine	85-7	2/28/85	9.1
Defeat Rdg.	Chestnut Oak	N. Hardwood	85-8	3/07/85	?
Bote Mt.	Chestnut Oak	Closed Oak	85-9	2/25/85	8.1
Tremont	Yellow Poplar	Cove Hardwood	85-10	2/17/85	8.1
Defeat Rdg.	Hemlock	N. Hardwood	85-11	3/14/85	11.5
Defeat Rdg.	Hemlock	Hemlock	85-12	3/15/85	8.6
PBR*	Yellow Poplar	Cove Hardwood	86-1	3/08/86	15.5

*Note PBR is the Parson Branch Road section of the study area.

a 5% reuse rate for bears in Pennsylvania. Johnson and Pelton (1981) found no reuse of dens in southern Appalachian forests and suggested that den reuse was directly related to the availability of den sites (ie., reuse as an index to general abundance of dens). Wathen (1983) agreed that den sites were abundant within the GSMNP, but reported a 7% occupancy rate of previously used dens. Smith (1985), working in a bottomland hardwood forest in Arkansas noted both an abundance of tree dens and a high rate (26%) of den reuse. Thus with conflicting reports of reuse in the literature and regional behavioral inconsistencies it is not clear whether the percentage or frequency of occurrence of den reuse has any social or biological significance in a bear population. However, it is recommended that the current method of tagging den trees continue; this could lead to valuable information about the formation, resilience and longevity of such trees and may provide insight into old-growth management and preservation..

Winter Dormancy and Denning Physiology

> Important to the physiologic and biochemical adaptation of the bear during denning is control of urea metabolism, so that uremia and dehydration do not occur. Studies of bears . . . have shown that the concentration of serum urea declines in winter. Associated with this change is an increase in serum creatinine. The net effect of these changes is a reduction in the ratio of serum urea to serum creatinine (U/C) from normal levels, above 25, to values less than 10. . . .
>
> . . . .
>
> An unexpected finding . . . was that U/C in some

> bears had reached denning levels in late summer and early fall, weeks before the animals denned. . . .
> . . . .
> Considering that there are few mammals, if any, with similar documented U/C values of 10 or less, we propose that the low value of U/C is a biochemical indicator of the hibernation state (Nelson 1984).

The previous information was derived from a 3 year field investigation conducted in west-central Colorado. To investigate such a relationship between the U/C ratio and winter dormancy of the black bear in the Southeast, I collected blood samples (N=33) during two June-September trapping seasons. Due to disturbance of the collection tubes after clotting, 4 samples were hemolyzed; leaving 29 (1984 N=15, 1985 N=14) for urea nitrogen and creatinine analysis. Additional samples, drawn from females captured in 1980-81 (N=34), were also analyzed. No blood samples were obtained during the extended trapping period (15 September to 18 November) conducted in 1985 and only 3 winter den samples (all post partum) were collected during 1986.

Results from 4 years of serum analysis were inconsistent and a Scheffe's multiple comparison failed to indicate any annual statistical differences ($P<0.5$) between summer (June-July), and late summer/early fall (August-September) parameters. Urea levels did decline seasonally, as suggested by Nelson (1984), during 1980 and 1985, but increased from June-July to August-September in 1981 and 1984. Creatinine, which theoretically should have increased, did so in 1981 and 1985, but showed decreases in 1980 and 1984. Despite the erratic behavior of urea and creatinine the U/C ratio did show seasonal declines in 3 of the 4 years examined (1980, 1981 and 1985) and in 2 of those years, (ie., 1980 and 1985) ratios were already below 25 in August and September. In fact, if a U/C ratio of 10 or less is indicative of the physiological state of hibernation, then 4 of 9 individuals captured during August and September 1980 were in "walking hibernation" (Nelson et al. 1983:285). Urea, and creatinine levels (mg/dl) and U/C ratios are presented in Table 15 and Figs. 13-15. The 3 samples taken from denned, postpartum females in winter 1986 yielded some surprising results. None of the U/C ratios were below 10, (prerequisite for the "physiologic state of dormancy") and only 1 was below a mammalian norm of 25. Two other den samples collected from "dormant" females in Pisgah National Forest, North Carolina in 1983 and 1984 (Brody 1984) showed similar U/C ratios non-representative of hibernation. Urea, creatinine and U/C ratios from these 5 winter den samples are presented in Table 16.

While sample sizes are generally small, preliminary findings from this study suggest that urea, creatinine and the U/C ratio may not be representative of dormancy for bears in the Southeast. Results are too contradictory to support the findings of Nelson (1984). Using a U/C ratio of < 10; individuals that were in dens and displaying

Table 15. Mean urea (U), creatinine (C) and U/C ratios in black bear serum collected June-September in GSMNP, Tennessee, 1980-1981 and 1984-1985.

Year	Trapping Period	N	Mean U (mg/dl)	Mean C (mg/dl)	U/C
1980	Jun-Jul	10	52.6	2.58	22.2
	Aug-Sept	9	38.6	2.22	17.2
1981	Jun-Jul	6	64.2	1.62	41.7
	Aug-Sept	9	67.6	2.37	33.5
1984	Jun-Jul	7	49.1	1.69	32.1
	Aug-Sept	8	65.8	1.39	48.2
1985	Jun-Jul	7	60.6	1.83	36.7
	Aug-Sept	7	42.7	1.85	23.9

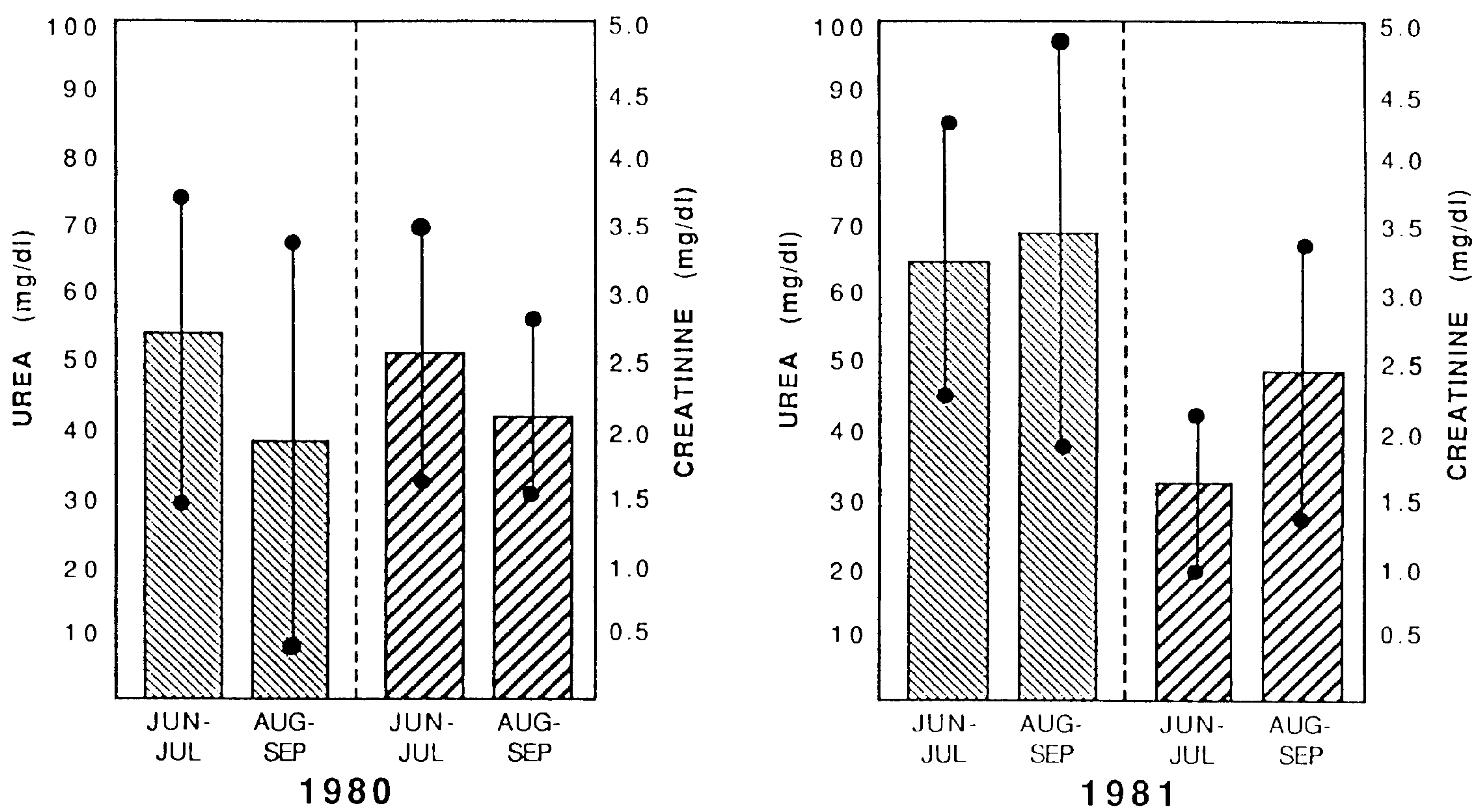

Figure 13. Mean urea and creatinine levels (mg/dl) in black bear serum collected June-September in GSMNP, Tennessee, 1980 and 1981.

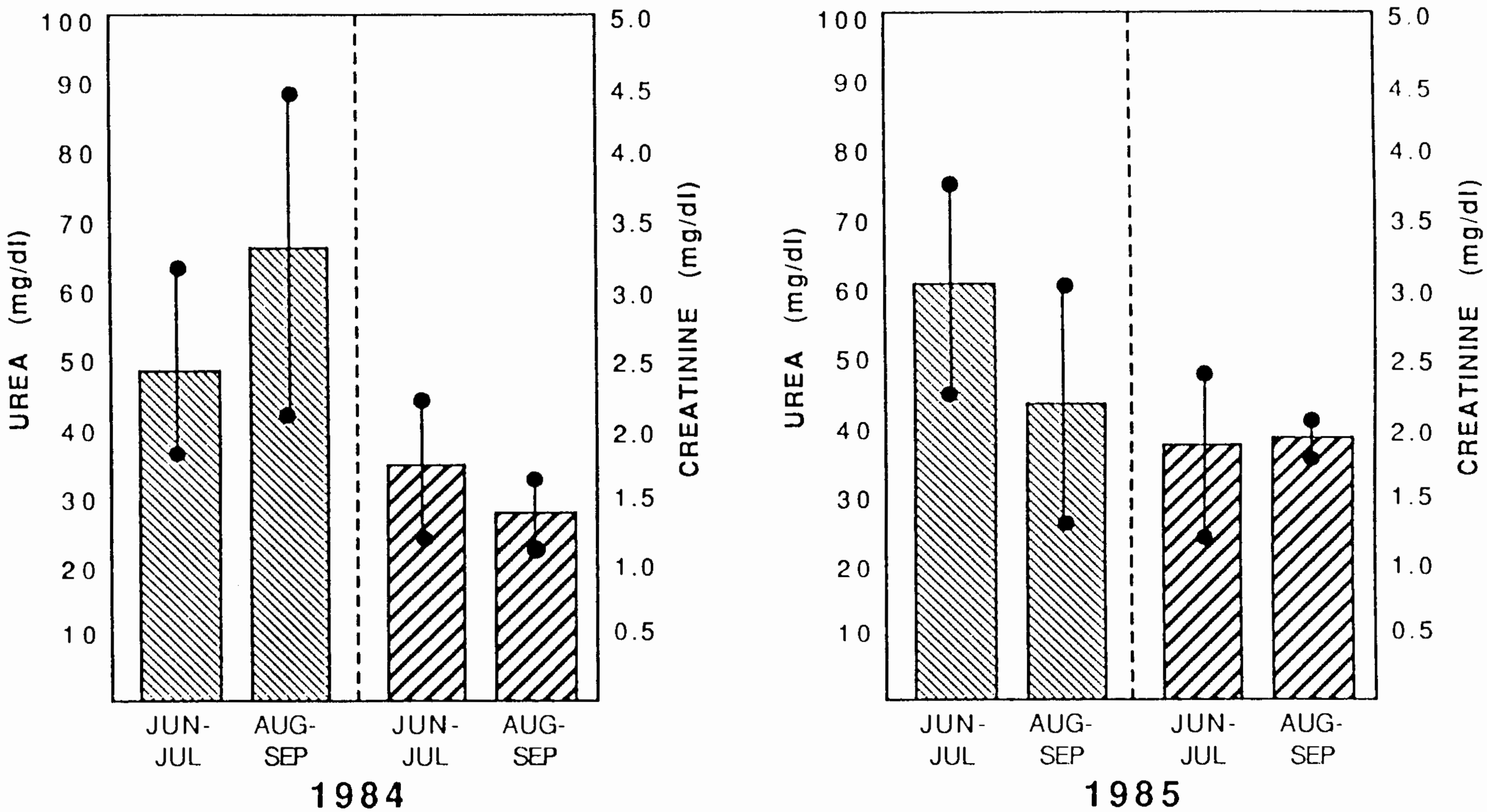

Figure 14. Mean urea and creatinine levels (mg/dl) in black bear serum collected June-September in GSMNP, Tennessee, 1984 and 1985.

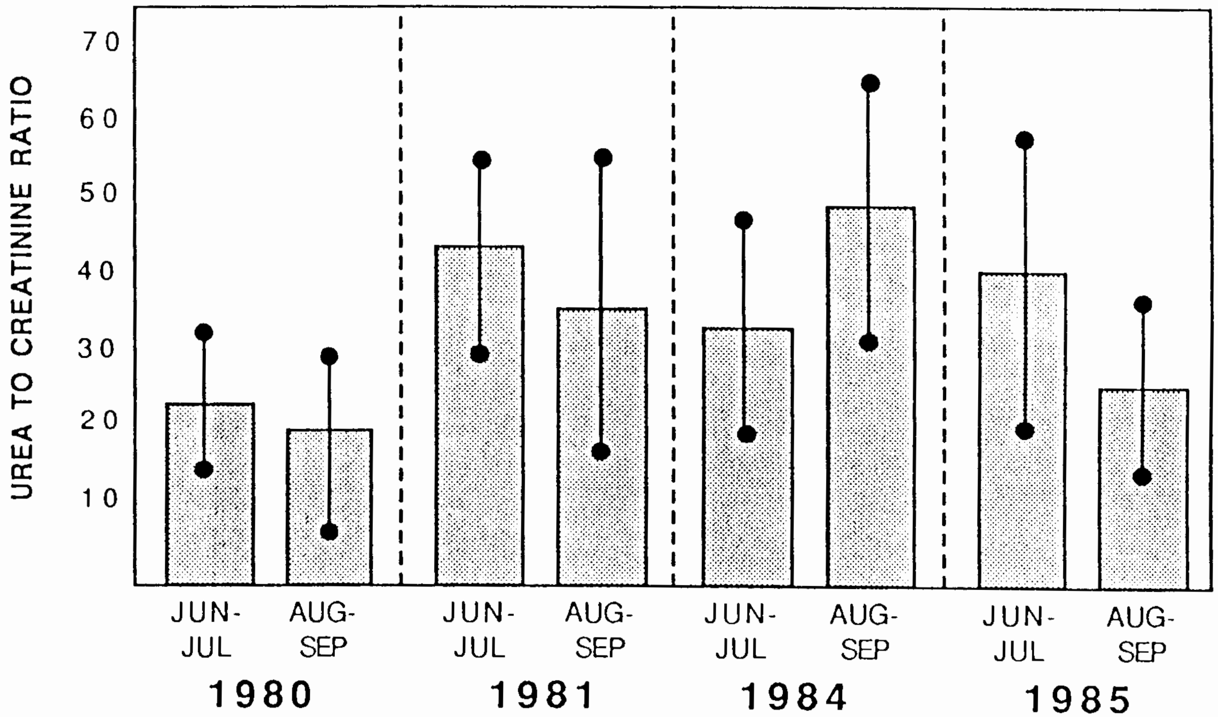

Figure 15. Ratio of urea to creatinine (U/C) in black bear serum collected June-September in GSMNP, Tennessee, 1980 - '81 and 1984 - '85.

Table 16. Ratio of urea to creatinine (U/C) in 5 winter den samples from female bears in Pisgah National Forest, North Carolina, and GSMNP, Tennessee, 1983-1986.

Study Area	Date Collected	Bear Tag#	U/C
Pisgah	3 February 1983	255	26.6
	25 February 1984	484	32.7
GSMNP	31 January 1986	659	46.9
	14 February 1986	476	34.0
	16 February 1986	532	14.6

traditional signs of lethargy (ie., hibernaculum curl, head "heaviness", body shivers and glazed eyes) showed no biochemical evidence of being dormant. On the other hand, I can find no ecological advantage for a bear to be in a physiologic state of hibernation 3 months prior to den entrance. Such "walking hibernation" could be advantageous in northern climates (ie., U/C ratios may reflect dormancy) given the short foraging period, severe weather conditions and lack of winter food. However, in the South, as suggested by Hellgren and Vaughan (1986), the availability of winter foods, and mild climatic conditions may make the circumvention of winter dormancy the most energy efficient means of survival.

Lastly, winter-active black bears (ie., individuals failing to den) have been reported by numerous researchers (Pers. obs., this study, Hellgren and Vaughan 1986, Carney 1985, Smith 1985, Hamilton and Marchinton 1980, Alt et al. 1976). However, information on the ratio of U/C in such bears is extremely limited. Hellgren and Vaughan (1986) obtained 2 samples from 1 winter-active bear captured in February in the Great Dismal Swamp and reported U/C ratios reflective of activity. While I was not able to obtain blood samples from bears that did not den during this study, observations of activity and bear disposition at densites showed a disparity in behavior between years. All cases of females failing to den (N=4), and aggressive den abandonments (N=2) occurred in the winter of 1985 (following the white oak mast failure of 1984). In 1986, following the bumper mast crop of 1985, no winter activity was observed and all females (N=6) were in a lethargic stupor. My observations suggest that black bears may achieve varying degrees of lethargy in response to body condition. If, as suggested by Smith (1985), body weight:stored fat ratios are the prerequisite for dormancy; then nutritional condition would be the ultimate stimulus for denning in areas where winter foraging is an energy efficient option.

Cubs

Litter Size and Sex Ratios

I examined 5 litters of newborn cubs and 1 litter after emergence from their tree den. Cubs were produced only in 1986. Litter size for 5 ground denning females ranged from 1 to 3 ($\bar{X}$=2.20). I could not verify litter size for the tree denning bear since at least 1 cub remained in the cavity during my observation of the female and 1 other offspring. The sex ratio favored females 2.7 : 1 (8 females, 3 males). I observed 2 litters of 2 cubs, 2 litters of 3 and 1 litter of 1 cub.

The mean litter size reported here is lower than that observed by either Wathen (1983:67; $\bar{X}$=2.58) or Eiler (1981:26; $\bar{X}$=2.60) for this same study area; yet sample size is too small to make any comparisons. However, the mean litter size of 2.20 does fall within the broad range of averages reported in other studies ($\bar{X}$=2.2 to 2.9; Harlow 1961, Collins 1973, Alt 1982, Smith 1985). Wathen (1983) reported a sex ratio in GSMNP favoring females 1.2 : 1, while Eiler observed a predominance of males in 17 litters within the same study area. Observations from 5 litters represent too small a sample to draw any conclusions about sex ratios.

Developmental Characteristics

I examined 5 litters in a 21 day period from 31 January to 20 February 1986. Weights of newborn cubs ranged from .36 kg to 1.68 kg ($\bar{X}$=.71 kg) and total length ranged from 25.5 cm to 42 cm ($\bar{X}$=29.82 cm) (Table 17). While I have no exact dates of parturition, I believe that 1 litter examined on 31 January and a second litter examined on 3 February were less than 1 week old. Umbilical scars were still scabbed and the cubs were sparsely furred. Nails and claws were well developed but still soft and ears were "pinned" back on the sides of the head. Eyes were just beginning to open in a litter of 3 cubs examined on 16 February and in a litter of a single cub; eyes were open completely on 20 February. I found no tooth eruption in any of the litters I examined.

Table 17. Weight (kg) and total length measurements (cm) for 11 black bear cubs examined between 31 January and 20 February 1986, in GSMNP, Tennessee.

Tag# Maternal Female	No. Cubs in Litter	Date Examined	Weight/cub (kg) Tot. Length/cub (cm)
659	3	1/31/86	0.36, 0.56, 0.50 25.5, 31.0, 28.0
722	2	2/03/86	0.42, 0.58 31.0, 24.5
476	2	2/14/86	0.58, 0.63 33.0, 34.0
532	3	2/16/86	1.10, 1.15, 1.20 36.0, 36.0, 37.0
731	1	2/20/86	1.68 42.0

CHAPTER V

SUMMARY AND CONCLUSIONS

1. One thousand sixteen (1,016) trapnights were used to capture 64 individual bears 69 times. Overall trapping success was 1 capture/14.7 trapnights. Thirty (30) individual females were captured 35 times resulting in a female trapping efficiency of 1 capture/29.0 trapnights.

2. Twenty six radiocollars were used to collar 24 female bears.

3. Fall trapping success for bears was poor, with 190 trapnights yielding only 2 captures (1 capture/95.0 trapnights). Bears are reluctant to investigate trap baits when natural foods are abundant.

4. Using hood-spring modified foot snares led to few trap injuries. No broken bones or dislocations were observed on 35 captured females.

5. Of 26 breakaway radiocollars deployed, 14 (53.8%) deteriorated or were removed by bears during the study.

6. Breakaway collar retention varied significantly between years (394 days, $N=10$ vs. 196 days, $N=5$, $P<0.05$); largely due to increased neck circumference of bears in good mast years.

7. In areas where annual recollaring is a problem (eg., the Southeast due to den inaccessability) breakaway radiocollars can result in a significant loss of data.

8. White oak mast differed dramatically during 1984 and 1985 (MPPI values of 8.74% and 35.06%, respectively).

9. Regression analysis showed a significant relationship between the white oak mast crop and the number of lactating females observed seasonally in GSMNP between 1979 and 1988 (winter: R^2=0.69, P<0.003, summer: R^2=0.45, P<0.03, annually: R^2=0.62, P<0.007).

10. White oak mast is critical to black bear productivity in the Southeast and during years of white oak mast failure, red oak seems to offer little nutritional compensation.

11. Minimum annual mortality rates calculated for adult females were 8.8% in 1984 and 5.9% in 1985.

12. Four of 6 bear deaths in this study were human caused and 3 of those instances involved poaching.

13. Using vulval examination, 12 of 35 females were observed in estrus. Most observations of estrus (ie., indicative of a breeding season) occurred between 20 June and 12 August.

14. Observations from this study suggest that severe white oak mast failures may alter the following years' estrous cycle. Reproductive synchrony may result following years of mast failure.

15. Females subjectively determined to be in estrus had significantly lower levels of estradiol ($\bar{X}$=11.06 pg/ml,

P<0.005) than females showing no signs of estrus (25.44 pg/ml).

16. Given the fact that bears are induced ovulators, estradiol levels may used in conjunction with vulval examination to differentiate between females that have bred and those that have not.

17. Salivary estradiols from females observed to be in estrus were lower than those observed in anestrus females; though not significantly ($\bar{X}$=10.12 pg/ml vs. $\bar{X}$=13.80 pg/ml, P>0.2).

18. Seven (7) of 29 bears $\geq$ 3.5 years old were lactating (24.1%) and 6 of these observations came in 1984. Following the mast failure of 1984 only 1 female was observed lactating.

19. Early weaning of cubs, due to excellent winter or spring condition of maternal females, may decrease the number of lactating females reported during a June to September trapping season.

20. Minimum reproductive age for female black bears in GSMNP was 5.2 years.

21. Mean age at first litter was affected largely by nutrition. Four reproductive skips were observed in "first litter" females following the mast failure of 1984.

22. Females entered dens from 5 December to 15 December during 1984-85 and from 27 November to 30 December

during 1985-86. Females delay den entry during years of abundant mast.

23. Den utilization data were compiled from GSMNP from 1978 to 1986. Based on frequency distributions, bears show a preference for tree denning in GSMNP; yet a majority of litters (16/29, 51%) were born to females denning on the ground. This behavior is likely due to nutrition. Females in good condition are predisposed to cub births yet their size may prevent them from entering tree cavities.

24. Thirteen den trees were tagged for future identification. One case of den reuse was observed, but it involved a ground den.

25. Urea, creatinine and U/C ratios were inconsistent in their seasonal behavior and results from 5 samples collected in winter dens (mean ratio of U/C = 30.96) suggest that the ratio of U/C may not be associated with dormancy in the Southeast.

26. Females either failed to den (N=4), were easily agitated or agressively abandoned dens during 1985. Females observed in 1986 were in a typical lethargic stupor.

27. Litter size as determined from 5 observations was 2.2 cubs/litter. Sex ratios favored females 2.7 : 1.

28. Four orphaned bear cubs were reintroduced during the winter of 1984-85. Releasing cubs in good condition just prior to the start of the denning season is a viable means of placing such bears back into a population.

LITERATURE CITED

LITERATURE CITED

Alt, G. L., F. W. Alt, and J. S. Lindzey. 1976. Home range and activity patterns of black bears in northeastern Pennsylvania. Proc. N. E. Sect. of Wildl. Soc. 33:45-56.

———. 1982. Reproductive biology of Pennsylvania's black bear. Pa. Game News 53(2):9-15.

———, and J. M. Gruttadauria. 1984. Reuse of black bear dens in northeastern Pennsylvania. J. Wildl. Manage. 48:236-239.

Ammons, A. E. 1974. Observations of reproductive activity of black bears in North Carolina, pp. 98-100. In M. R. Pelton and R. H. Conley eds. Proceedings of second eastern workshop on black bears, Gatlinburg, TN. 242 pp.

Anonymous. 1902. A Report to the Secretary of Agriculture in Relation to the Forests, Rivers, and Mountains of the Southern Appalachian Region. U. S. Govt. Printing Office. Washington, D. C. 201 pp.

Anonymous. 1945. Soil Survey, Sevier County. U.S. Dept. of Agric., Univ. Tenn. Agric. Exp. Station, and Tenn. Valley Authority. 119 pp.

Beecham, J. J. 1980. Population characteristics, denning and growth patterns of black bears in Idaho. Unpubl. Ph.D. Dissertation, Univ. of Montana, Missoula. 101 pp.

Beeman, L. E. 1975. Population characteristics, movements, and activities of the black bear (Ursus americanus) in the Great Smoky Mountains National Park. Unpubl. Ph.D. Diss., Univ. of Tennessee, Knoxville. 218 pp.

Brody, A. J. 1984. Habitat use by black bears in relation to forest management in Pisgah National Forest, North Carolina. M.S. Thesis, Univ. of Tennessee, Knoxville. 123 pp.

Cain, S. A. 1930. Certain floristic affinities of the trees and shrubs of the Great Smoky Mountains and vicinity. Butler Univ. Bot. Studies. 1:129-150.

Carney, D. W. 1985. Population dynamics and denning ecology of black bears in Shenandoah National Park, Virginia. M.S. Thesis, Virginia Poly. Inst. and State Univ., Blacksburg. 84 pp.

Carr, P. C. 1983. Habitat utilization and seasonal movements of black bears in the Great Smoky Mountains National Park. M.S. Thesis, Univ. of Tennessee, Knoxville. 95 pp.

Collins, J. M. 1973. Some aspects of reproduction and age structures in the black bear in North Carolina. Proc. S. E. Assoc. Game and Fish Comm. 27:163-170.

———. 1985. The black bear in North Carolina. North Carolina Wildlife Resources Commission. Fed. Aid Project W-57. 16 pp.

Crocker, C. L. 1967. Rapid determination of urea nitrogen in serum or plasma without deproteinization. Am. J. Med. Tech. 33:361.

Dickson, R. R. 1960. Climates of the states: Tennessee. U.S. Dept. of Commerce, Weather Bureau, Climatology of the U. S., No. 60-40. 16 pp.

Downs, A. E., and W. E. McQuilken. 1944. Seed production of Southern Appalachian oaks. J. For. 42:913-920.

Eagle, T. C., and M. R. Pelton. 1978. A tooth sectioning and simplified staining technique for aging black bears in the southeast. Proc. East. Black Bear Workshop 4:92-98.

———, and ———. 1983. Seasonal nutrition of black bears in the Great Smoky Mountains National Park. Int. Conf. Bear Res. and Manage. 5:94-101.

Eiler, J. H. 1981. Reproductive biology of black bears in the Smoky Mountains of Tennessee. M.S. Thesis, Univ. Tennessee, Knoxville. 117 pp.

———, W. G. Wathen, and M. R. Pelton. 1989. Reproduction of black bears in the Southern Appalachian mountains. J. Wildl. Manage. 53:353-360.

Elowe, K. D. 1987. Factors affecting black bear reproductive success and cub survival in Massachusetts. Ph.D. Dissertation, Univ. Massachusetts, Amherst. 82 pp.

Erickson, A. W. 1957. Techniques for live-trapping and handling black bears. Trans. N. Am. Wildl. and Nat. Res. Conf. 22:520-543.

———, and J. E. Nellor. 1964. Breeding biology of the black bear, pp. 5-45. In The black bear in Michigan. Michigan Agric. Exp. Stn. Res. Bull. 4.

Fennemans, N. M. 1938. Physiography of the Eastern United States. McGraw-Hill, New York. 714 pp.

Foresman, K. R., and J. C. Daniel, Jr. 1983. Plasma progesterone concentrations in pregnant and non-pregnant black bears (Ursus americanus). J. Reprod. Fert.

Frome, M. 1985. America's Favorite National Parks. Prentice Hall, Englewood, New Jersey. 80 pp.

Golden, M. S. 1974. Forest vegetation and site relationships in the central portion of the Great Smoky Mountains National Park. Ph.D. Dissertation, Univ. of Tennessee, Knoxville. 275 pp.

Graber, D. M. 1981. Ecology and management of black bears in Yosemite National Park. Ph.D. Dissertation, Univ. of California, Davis. 206 pp.

Grenfell, W. E., Jr., and A. J. Brody. 1983. Seasonal foods of black bears in Tahoe National Forest, California. Calif. Fish and Game 69(3):132-150.

Griess, J. M. 1987. River otter reintroduction in Great Smoky Mountains NAtional Park. M.S. Thesis, Univ. of Tennessee, Knoxville. 109 pp.

Gysel, L. W. 1957. Acorn production on good, medium, and poor sites in southern Michigan. J. For. 55:570-574.

Hafez, E. S. E. 1980. Reproduction in Farm Animals. Fourth Ed. Lea and Febiger Co., Philadelphia. 627 pp.

Hamilton, R. J., and R. L. Marchinton. 1980. Denning and related activities of black bears in the coastal plain of North Carolina. Int. Conf. Bear Res. and Manage. 4:121-126.

Harlow, R. F. 1961. Characteristics and status of Florida black bear. Trans. N. Am. Wildl. and Nat. Res. Conf. 26:481-495.

Heinegard, D., and G. Tiderstrom. 1973. Determination of serum creatinine by a direct calorimetric method. Clin. Chem. Acta. 43:305.

Hellgren, E. C., and M. R. Vaughan. 1986. Home range and movements of winter-active black bears in the Great Dismal Swamp. Int. Conf. Bear Res. and Manage. 7:227-234.

———, D. W. Carney, N. P. Garner, and M. R. Vaughan. 1988. Use of breakaway cotton spacers on radio collars. Wildl. Soc. Bull. 16:216-218.

Hugie, R. D. 1982. Black bear ecology and management in the northern conifer-deciduous forests of Maine. Ph.D. Dissertation, University of Montana, Missoula. 203 pp.

Jenness, R. 1985. Biochemical and nutritional aspects of milk and colostrum, pp. 164-197. In B. L. Larson, ed. Lactation. Iowa State Univ. Press, Ames, Iowa. 276 pp.

Johnson, K. G. 1978. Den ecology of black bears (Ursus americanus) in the Great Smoky Mountains National Park. M.S. Thesis, Univ. of Tennessee, Knoxville. 107 pp.

———, and M.R. Pelton. 1980. Prebaiting and snaring techniques for black bears. Wildl. Soc. Bull. 8(1):46-54.

———, and ———. 1981. Selection and availability of dens for black bears in Tennessee. J. Wildl. Manage. 45:111-119.

Jonkel, C. J., and I. McT. Cowan. 1971. The black bear in the spruce-fir forest. Wildl. Monogr. 27. 57 pp.

Kemp, G. A. 1976. The dynamics and regulation of black bear, Ursus americanus, populations in northern Alberta. Int. Conf. Bear Res. and Manage. 3:191-197.

King, P. B., and A. Stupka. 1950. The Great Smoky Mountains--Their geology and natural history. Sci. Month. 61:31-43.

———, R. B. Neuman, and J. B. Hadley. 1968. Geology of the Great Smoky Mountains National Park, Tennessee and North Carolina. Geol. Surv. Prof. Paper 587. 23 pp.

Lambert, R. S. 1961. Logging the Great Smokies, 1880-1930. Tennessee Hist. Quart. 20:350-363.

LeCount, A. L. 1980. Some aspects of black bear ecology in the Arizona chapparal, pp. 175-179. In C. J. Martinka and K. L. McArthur, eds., Bears-Their biology and management. Bear Biol. Assoc. Conf. Ser. Publ. 3, 375 pp.

———. 1983. Evidence of wild black bears breeding while raising cubs. J. Wildl. Manage. 47:264-268.

Lentz, W. M., R. L. Marchinton, and D. M. Carlock. 1981. Black bear habitat in north Georgia: some implications of wilderness designation. Proc. Ann. Conf. S. E. Assoc. Fish and Wildl. Agencies. 34:550-556.

Linzey, A. V., and D. N. Linzey. 1971. Mammals of the Great Smoky Mountains National Park. Univ. of Tennessee Press.

Matson, G.M. 1981. Workbook for Cementum Analysis. Matson's Publishing Co., Milltown, Montana. 30 pp.

Mech, L. D. 1983. Handbook of Animal Radio-tracking. Univ. of Minnesota Press, Minneapolis. 107 pp.

Miller, R. L., E. R. McCaffrey, and G. B. Will. 1973. Recent capture and handling techniques for black bears in New York. Trans. N. E. Sect. Wildl. Soc. 30:117-137.

Nelson, R. A., H. W. Wahner, J. D. Jones, R. D. Ellefson, and P. E. Zollman. 1973. Metabolism of bears before, during, and after winter sleep. Am. J. Physiol. 224(2):491-496.

———. 1980. Protein and fat metabolism in hibernating bears. Fed. Proc. 39(12):2955-2958.

———, G. A. Folk, E. W. Pfeiffer, J. J. Craighead, C. J. Jonkel, and D. L. Steiger. 1983. Behavior, biochemistry, and hibernation in black, grizzly, and polar bears. Int. Conf. Bear Res. and Manage. 5:284-290.

———, T. D. I. Beck, and D. L. Steiger. 1984. Ratio of serum urea to serum creatinine in wild black bears. Science. 226:841-842.

Nicholas, N. S., and P. S. White. 1984. Great Smoky Mountains National Park hard mast survey: An evaluation of the current survey, analysis of past data and discussion of alternatives for future use. U. S. Dept. of Interior, National Park Service, Research/Resources Mgmt. Report SER-68. 66 pp.

O'Pezio, J., S. H. Clarke, and C. Hackford. 1983. Chronology of denning by black bears in the Catskill region of New York. N. Y. Fish and Game J. 30(1):1-11.

Payne, N. F. 1978. Hunting and management of the Newfoundland black bear. Wildl. Soc. Bull. 6:206-211.

Poelker, R. T., and H. D. Hartwell. 1973. Black bear of Washington. Wash. State Game Dept. Biol. Bull. 14. 180 pp.

Pozzanghera, S. A., B. D. Nolan Jr., and M. R. Pelton. 1986. Inducing salivation in immobilized black bears for the purpose of estrogen analysis, pp. 168-173. In D. D. Martin ed. Proc. of the eighth eastern workshop on black bear research and management, Williamsburg, VA. 249 pp.

Rausch, R. L. 1961. Notes on the black bear, Ursus americanus Pallas, in Alaska, with particular reference to dentition and growth. Zeitschrift fur Saugetierkunde. 26:77-107.

Raybourne, J. W. 1976. A study of a black bear population in Virginia. Trans. N. E. Sect. Wildl. Soc. 33:71-81.

Reynolds, D. G., and J. J. Beecham. 1980. Home range activities and reproduction of black bears in west-central Idaho, pp. 181-190. In, C. J. Martinka and K. L. McArthur, eds. Bears-Their biology and management. Bear Biol. Assoc. Conf. Ser. Publ. 3, 375 pp.

Rogers, L. L. 1976. Effects of mast and berry crop failures on survival, growth, and reproductive success of black bears. N. Am. Wildl. Nat. Res. Conf. 41:431-438.

———. 1977. Social relationships, movements, and population dynamics of black bears in northeastern Minnesota. Ph.D. Dissertation, Univ. of Minnesota, Minneapolis. 194 pp.

———. 1987. Effects of food supply and kinship on social behavior, movements and population growth, of black bears in northeastern Minnesota. Wildl. Monogr. 97. 72 pp.

Shanks, R. E. 1954a. Climates of the Great Smoky Mountains. Ecology. 35:354-361.

———. 1954b. Reference list of native plants of the Great Smoky Mountains. Botany Dept., Univ. of Tennessee, Knoxville. 14 pp.

Sharp, W. M. 1958. Evaluating mast yields in the oaks. Penna. Agric. Exper. Sta. Bull. 635. 22 pp.

———, and V. G. Sprague. 1967. Flowering and fruiting in the white oaks. Pistillate flowering, acorn development, weather, and yields. Ecology. 48:243-251.

Smith, T. R. 1985. Ecology of black bears in a bottomland hardwood forest in Arkansas. Ph.D. Dissertation, Univ. of Tennessee, Knoxville. 209 pp.

Stephens, L. A. 1969. A comparison of climatic elements at four elevations in the Great Smoky Mountains. M.S. Thesis, Univ. of Tennessee, Knoxville. 119 pp.

Strickland, M. D. 1972. Production of mast by selected species of oak (Quercus sp.) and its use by wildlife on the Tellico Wildlife Management Area, Monroe County, Tennessee. M.S. Thesis, Univ. of Tennessee, Knoxville. 62 pp.

Stupka, A. 1960. Great Smoky Mountains National Park natural history handbook, No. 5. U. S. Govt. Printing Office, Washington, D. C. 75 pp.

Thornthwaite, C. W. 1948. An approach toward a rational classification of climate. Geog. Rev. 38:55-94.

Uhlig, H. G., and H. L. Wilson. 1952. A method of evaluating an annual mast index. J. Wildl. Manage. 16:338-343.

Walker, R. F. 1983. Assessment of endocrine function by salivary steroids. Reproduction. 15(2):1-2.

Wathen, W. G. 1983. Reproduction and denning of black bears in the Great Smoky Mountains. M.S. Thesis, Univ. of Tennessee, Knoxville. 135 pp.

Whitehead, C. J. 1969. Oak mast yields on Wildlife Management Areas in Tennessee. Unpub. Report. Tenn. Game and Fish Commission, Nashville. 11 pp.

Whittaker, R. H. 1956. Vegetation of the Great Smoky Mountains. Ecol. Monogr. 26:1-80.

Willey, C. H. 1974. Aging black bears from first premolar tooth sections. J. Wildl. Manage. 38:97-100.

Wimsatt, W. A. 1963. Delayed implantation in the Ursidae, with particualar refernce to the black bear, pp. 49-76. In A. C. Enders, ed. Delayed Implantation. Univ. of Chicago Press, Chicago. 653 pp.

APPENDICES

APPENDIX A

The Use of Burlap to Construct Bear Cubbies

One "set" often used to capture animals with spring-activated foot snares is the cubby. Quite simply, the cubby is a feature used to guide the movements of the target animal into the snare loop and onto the trigger. Natural cubbies (eg., hollow stumps, slash piles and exposed root masses) can be used quite effectively, but are often times not readily available at a trap site. Cubbies used to trap bears are usually constructed of tree trunks, large limbs and branches piled against the sides of a standing tree. The walls created by the stacking of these materials are formed into a V-shape that funnels the movements of the bear into the snare. The cubby set is a standard for capturing bears with foot snares and the technique is very effective, yet problems can arise in areas where bears have become trap wary. Bears that are familiar with snares and cubby sets will rob a trap by tearing down the walls of a cubby and entering from the side. Reconstructing cubbies after robberies and/or captures can be frustrating and time consuming.

In 1984 in an effort to increase trapping efficiency and decrease the amount of time spent rebuilding "robbed" cubby sets within GSMNP, I began using burlap sheeting for cubby material. The material was bought in rolls 4'x 150' and cut into 12'sections. The sections were easily carried in backpacks and installed quickly at trap sites. The midpoint of the burlap was placed around a chosen tree and the two sides were stretched tight and the ends rolled onto support sticks. The snare and throwing arm assembly along with the stepping box was then installed. The support sticks could be moved apart or brought together to bring the burlap walls of the cubby in contact with the stepping box. Once the burlap was in the correct location the support sticks were driven into the ground. The bottom edge of the burlap was then be covered with leaf litter to keep it in contact with the ground and prevent bears from reaching under the edge. A schematic drawing of the burlap cubby is presented in Figure 16.

The burlap cubbies took less than 5 minutes to set up at an established site and worked well. I have no comparative trapping data, but the burlap was used during the second half of the 1984 trapping season and exclusively during 1985. Pieces of burlap were fairly resistant and numerous captures could be made with the same piece. Large tears were simply knotted shut, and small holes seemed to cause no problems in the effectiveness. Trap robberies did occur with burlap cubbies, most noticeably during the second year of their use, but this led to the creation of a set utilizing the crumpled heap of burlap from an apparent robbery as a cover for the snare and throwing arm.

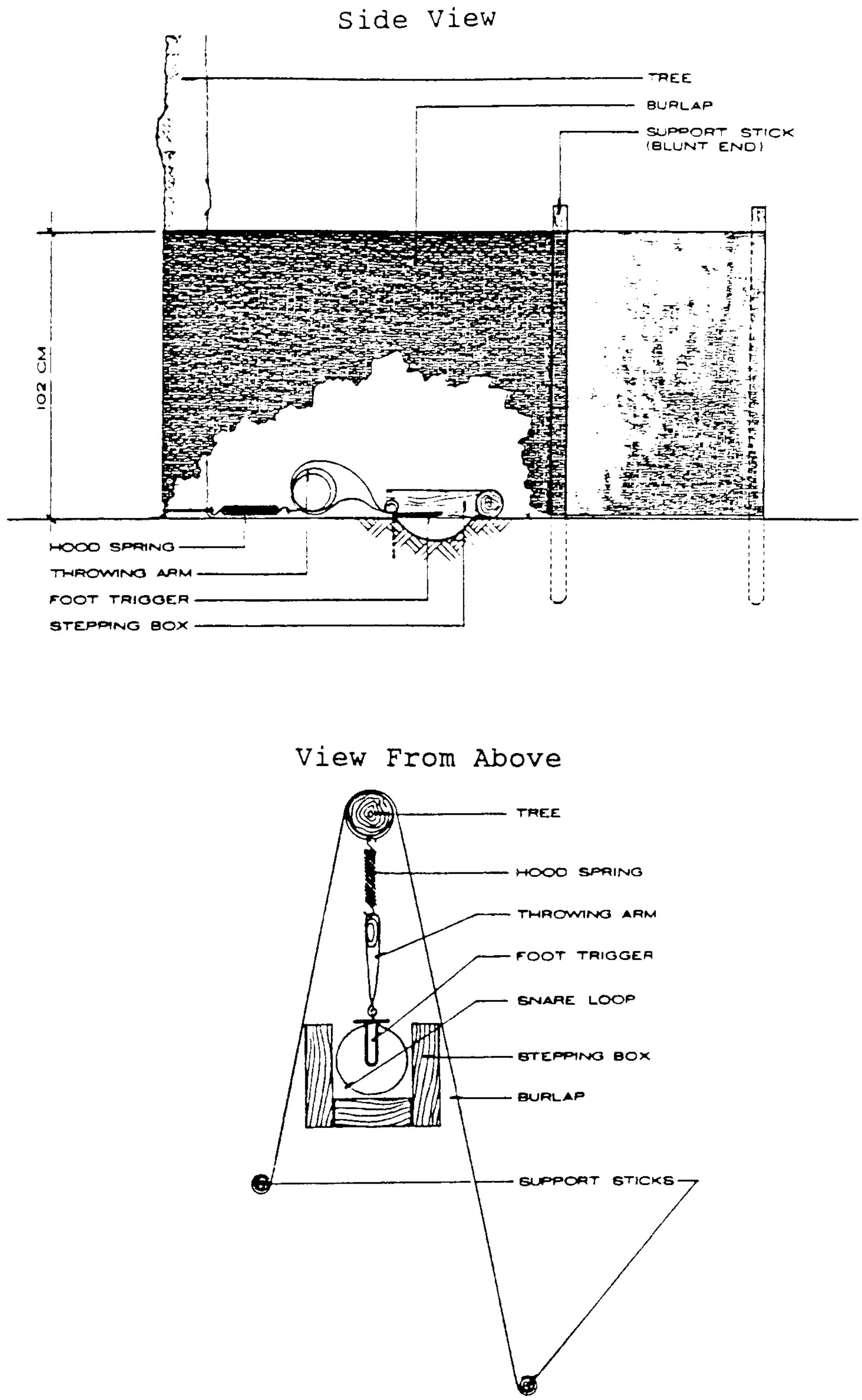

Figure 16. A schematic drawing of a burlap cubby used to capture black bears in GSMNP, Tennessee.

One potential problem with the use of burlap as a cubby material is the entangling of the snare and throwing arm assembly; thereby leading to bear injury. While I observed no cases of burlap related injuries in two years, researchers in the GSMNP (Stiver, pers. comm.), currently using burlap, have seen occasional instances of reduced cable swivel and hood-spring effectiveness due to burlap entanglement. The use of burlap as a cubby material should be evaluated further.

APPENDIX B

Orphaned Cub Reintroductions

Resource managers at GSMNP and members of the University of Tennessee College of Veterinary Medicine (UTCVM) rehabilitated 16 orphaned bear cubs during 1984 (Bill Cook, pers. comm.). The majority of cubs were orphaned as a result of poaching, automobile accidents and harassment by dogs. Four (4) of these 16 cubs were obtained late in the year (October and November) and held just prior to the onset of the denning season. Of these 4, 3 cubs (2 females and 1 male) had suffered only minor injuries and during their stay in captivity became markedly obese on a diet of high protein dog food, fruits and meat scraps. The one remaining cub (a male 715) had been struck by a car during mid October and held at UTCVM following surgery to set and pin a fractured left tibia. The cub was also believed to have partial vision loss. The bear was released from UTCVM on November 28 and joined the other 3 cubs at a holding facility within the Park.

On 30 November 1984, Park Service biologists' and technicians and University affiliates (myself included) sedated the 4 cubs, collected measurements, blood samples and other biological data and ear-tagged and tattooed the bears for future identification. The cubs were equipped with modified breakaway radiocollars and transported to the upper Elkmont section of the study area where they were released.

While not an original goal of this project, the opportunity to investigate the post release behavior of orphaned cubs is certainly noteworthy. The intent of the radiocollaring was to determine whether late season releases of orphaned cubs is a viable means of reintroducing such bears back into a population. The following is a brief account for each individual: Female 716 was released in excellent condition at a weight of 16 kg (35 pounds). She showed no signs of pre-denning lethargy (Johnson and Pelton 1979, Beecham et al. 1983) while in captivity and was observed eating, drinking and defecating regularly up until the time of her release. She moved NE of the release site and was determined (via aerial tracking) to be denned as of 13 December 1984 (13 days post release). Her den was located on 3 March 1985, 6 km from the release site, approximately 13 m up in a Carolina silverbell (Halesia Carolina). She exited her den during early April and periodic monitoring during May, June, and July indicated regular movements (ie., establishment of a home range) centered 7 km N of the release site. A telemetry check on 4 August put her location 3.2 km NW of the release site and in close proximity to a well traveled road. Following a similar location obtained on 13 September 1985, I homed in on the signal and located her collar. The collar had been cut and removed from the bear and was further damaged by a small round hole. An X-ray of the collar showed lead fragments around the hole; the size was indicative of a .22 caliber bullet. I assumed this bear was poached. The last radio telemetry check away from the location where I found the collar was on 15 July. The bear survived a minimum of 227 days from the time of its release and was 1.5 years old at the time of its death.

Male cub 713/714 was in excellent health and vigor prior to his release. The bear weighed 19.5 kg (43 pounds) and fed actively during his stay in captivity. No signs of lethargy were noted in this bear. Following release the bear moved approximately 17.7 km E, NE and was determined to be denned by 13 December (13 days post release). Although the den was not visited, it "appeared" (telemetrically) from the air that the bear was within a large standing snag 0.8 km NE of Devil's Courthouse peak. The bear was monitored periodically from May (after den emergence) to November 1985 and traveled widely; often crossing the Appalachian Trail. The last location prior to transmitter failure was on 27 November 1985. At that time the bear was 19.5 km from the release site and S of the Appalachian Trail at Mineral Gap in North Carolina. The bear had been monitored 362 days before I lost radio contact and was 1.8 years old.

Female 422/674 was acquired with male 713/714 and it is likely that the two were siblings. She was the larger of the two female cubs and weighed 18.6 kg (41 pounds). Her health and appetite was excellent and she, like the two previous cubs, showed no sign of winter lethargy while in captivity. Upon release she traveled with male 713/714 but was determined to be denned two days earlier than he (11 December, 11 days post release). She denned 19 km from the release site and within 1.6 km of the den chosen by 713/714. Her den was not visited. She emerged in late April and radio contact was maintained until 15 July 1985 when her transmitter expired. At last location the bear was within the study area, 1.9 km N of Brier Ridge Peak just S of Thunderhead Prong. She had centered her activities in this area; approximately 17.7 km from the release site. She survived a minimum of 227 days prior to signal loss and was 1.5 years old.

The last cub, male 715, was the individual that had been struck by a car and held at UTCVM following surgery. Upon release on 30 November, the cub was reluctant to leave. A check of the area by NPS personnel 1 day later (1 December) found the cub to be in the same location. He was wet and shivering and was easily approached and subdued. He was brought back to the holding facility at Park headquarters where he remained until 31 January 1985. During this extended period of captivity, the bear ate well, "became markedly obese and progressively more lethargic" (Cook 1985). On 31 January 1985, the 21 kg (46 pound) bear was sedated and refitted with his radiocollar. He was transported to the upper Elkmont section of the study area near Little River and placed inside an American chestnut (Castanea dentata) stump. The stump was "sealed" using tree bark, branches and leaf litter. Throughout the winter and spring periodic checks of the bear were made by NPS personnel. The bear appeared to fare well in his constructed den, but showed no signs of trying to emerge. In May, a NPS wildlife technician dismantled the densite and prompted the bear to leave. Upon exiting the stump the bear appeared to be in good condition, ran a short distance and climbed a tree. Periodic telemetry checks were made during May, June and July. All locations of the bear were within 1.6 km of the densite. Repeated locations in the same area were noticed in August and September, however I was not able to home in on the animal until 3 November 1985. I located the collar and remains of the bear carcass approximately 1.6 km from the densite. Decomposition was too extensive to draw any conclusions about the death of the bear, but I believe that it had been in place since August. The last location of the bear away from the site where I found the carcass was on 12 July 1985. Following his second "release" the bear was alive for a minimum period of 162 days and was 1.5 years old at the time of his death.

Results from the late season reintroduction of these 4 orphaned cubs is encouraging. Despite the fact that 2 individuals did not survive, all bears denned successfully. The "success" of the denning efforts of 715 must be evaluated in a different light. The idea of a bear surviving a forced hibernaculum poses some interesting questions about the physiologic state of dormancy in black bears (see Winter Dormancy and Denning Physiology in RESULTS AND DISCUSSION). Male 715, while lethargic, was observed eating, drinking, urinating and defecating the day prior to his forced denning. The "state" of dormancy which Nelson (1980) describes includes independence from food and water and the cessation of urination and defecation. Nelson (1980) noted 2 deaths of captive bears that " . . . failed to achieve the state of hibernation"; these bears lost 30% of their mass in less than 3 weeks, urinated in their dens and had toxic levels of urea within their bloodstream. I had speculated (see University of Tennessee 1984 Annual Progress Report) that male 715 would suffer the same consequences. He did not, and an inspection of the den after emergence found it free of feces and urine. Despite physical signs indicative of an active bear (albeit lethargic), male 715 survived a forced hibernaculum of over 3 months; suggesting that bears may be able to alter their state of lethargy in response to a drastic change in environmental stimuli. In any event, releasing rehabilitated bear cubs just prior to the onset of the denning season appears to be a valid method of reintroducing such bears back into a population.

APPENDIX C

Table 18. Capture, tagging and radiocollar information for females captured in the northwest quadrant of GSMNP, Tennessee, 1984-1985.

Bear Tag#	Capture Date	Recapture (No)	Recapture (Yes)	Capture Location	Age (Years)	Weight (kg)	Transmitter Frequency
702	17 June 1984	N		SUG	3.5	30	151.230
703	18 June 1984	N		SUG	2.5	20	None
706	23 June 1984	N		SUG	4.5	34	151.210
653	5 July 1984		Y	BOTE	6.5	45	151.470
510	7 July 1984		Y	BOTE	5.5	41	151.680
711	21 July 1984	N		DFT	7.5	41	150.020
712	25 July 1984	N		DFT	6.5	36	151.520
550	26 July 1984		Y	BOTE	7.5	25	151.450
711	29 July 1984		Y	DFT	7.5	41	151.790
610	4 Aug 1984		Y	PBR	5.5	39	151.385
609	6 Aug 1984		Y	PBR	4.5	49	151.325
709	6 Aug 1984	N		TPR	7.5	34	151.590
486	10 Aug 1984		Y	TPR	8.5	45	151.363
717	14 Aug 1984	N		UT	7.5	45	151.334
718	15 Aug 1984	N		UT	4.5	36	151.690
710	15 Aug 1984	N		TPR	6.5	39	151.280
737	27 Aug 1984		Y	PBR	8.5	52	151.415
722	20 June 1985	N		SUG	3.5	34	151.440
659	25 June 1985		Y	TPR	6.5	39	151.140
476	28 June 1985		Y	TPR	12.5	45	150.100
723	29 June 1985	N		TPR	2.5	20	None

Table 18 (continued)

Bear Tag#	Capture Date	Recapture (No)	Recapture (Yes)	Capture Location	Age (Years)	Weight (kg)	Transmitter Frequency
806	17 July 1985		Y	PBR	3.5	44	151.770
808	18 July 1985	N		PBR	5.5	36	151.741
727	18 July 1985	N		BOTE	?	50	151.050
710	31 July 1985		Y	TPR	7.5	41	151.661
723	4 Aug 1985		Y	TPR	2.5	25	None
532	4 Aug 1985		Y	TPR	5.5	50	151.720
429	12 Aug 1985		Y	PBR	10.5	59	151.033
609	12 Aug 1985		Y	PBR	5.5	59	None
814	16 Aug 1985	N		PBR	7.5	48	None
611	16 Aug 1985		Y	PBR	4.5	41	None
609	16 Aug 1985		Y	PBR	5.5	59	None
813	19 Aug 1985	N		PBR	4.5	68	None
730	18 Sept 1985	N		SUG	2.5	25	None
731	19 Sept 1985	N		SUG	4.5	34	150.042

SUG = Sugarland Mountain
BOTE = Bote Mountain
DFT = Defeat Ridge
PBR = Parson Branch Road
TPR = Turkeypen Ridge
UT = Upper Tremont

VITA

Stephen Anthony Pozzanghera, son of Sam and Connie Pozzanghera, was born in Rochester, New York, on 10 December 1961. He attended Fairport High School in Fairport, New York, and graduated in 1980. He then attended West Virginia University in Morgantown, West Virginia, and graduated in May of 1984 with a Bachelor of Science degree in Wildlife Management. He began graduate studies at the University of Tennessee, Knoxville, in June of 1984 in the Department of Forestry, Wildlife, and Fisheries. In March of 1987, while in the writing stage of his thesis, he accepted a position with The North Carolina Wildlife Resources Commission. He was married to Elizabeth Childs in May of 1987 and graduated with a Master of Science degree in Wildlife and Fisheries Science from the University of Tennessee, Knoxville, in December 1990.